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A
TREATISE
ON
GEOLOGY.

PRINTED BY NEILL AND CO. OLD FISHMARKET,
EDINBURGH.

Drawn with Camera Lucida, by Thos Allan, Esqr F.R.S.E.

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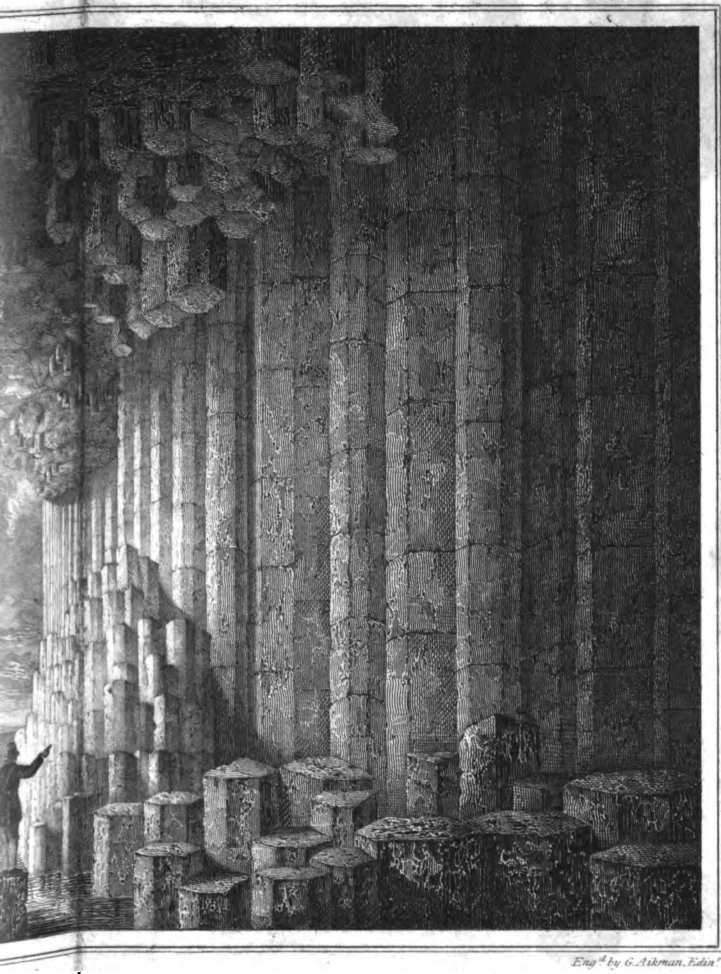
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A

TREATISE

ON

GEOLOGY,

FORMING THE ARTICLE UNDER THAT HEAD IN

THE SEVENTH EDITION OF THE

ENCYCLOPÆDIA BRITANNICA.

BY

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A "GUIDE TO GEOLOGY," &C.

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ADAM AND CHARLES BLACK, NORTH BRIDGE,

BOOKSELLERS TO HIS MAJESTY FOR SCOTLAND.

MDCCCXXXVII.

D.

PREFACE.

My object in this Treatise has not been to collect together the enormous mass of observed facts which now constitute the wide foundation of geological truths, but to exemplify the most important of these truths by discussing the phenomena in a certain order, under the guidance of admitted general principles. These principles, with regard to the constitution of the globe, whether derived from other sciences or ascertained by geological inquiry, being established, the different systems of strata are reviewed in succession, for the purpose of determining the physical conditions under which chemical and mechanical agencies were put in activity. After treating methodically of the Stratified and Superficial Deposits, and Volcanic Products, the state of Geological Theory is considered with reference to some great problems which must be solved before any general agreement can be expected among geologists.

In order to deliver in a small compass a clear exposition of the leading views of modern Geology, supported by a sufficient basis of phenomena, it was requisite to retrench from the article every superfluity, and particularly to reject all criticism of the vague and idle hypotheses which preceded a rational investigation of the History of the Earth.

J. P.

York, 1st *May* 1837.

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The reasoning employed in geology is, for the most part, analogical. Observation of the phenomena which now take place in nature, gives us the characteristic effects of modern agencies or causes; comparison of these phenomena with those produced in ancient geological periods, determines the agreement or disagreement in their respective causes; the object of sound geology is to combine the whole series of observed phenomena and inferred causes or agencies into one general history of the successive conditions of our globe, and the changes which have happened to it since the epoch when the present laws of organic and inorganic nature were appointed. We cannot assume that these laws have always been operating under the same circumstances as now, but we are justified in admitting, as a basis of reasoning, that similar natural circumstances in past and present times were consequences of similar preceding agencies, and productive of similar subsequent effects. It is evident that, in proportion to our knowledge of the cha-

racteristic effects of modern agencies, separate and combined, will be the power of referring to their proximate causes the phenomena of ancient nature; the more correct and complete this knowledge, the more exact and extensive is the basis of geological theory. The influence of a right view of existing nature is also sensible in directing the researches of observers towards the most important and characteristic circumstances of the phenomena which are to be explained.

The laws of nature are constant, but so adjusted to the material world that the effects they produce are proportioned to quantity and kind of matter, situation and direction of action, and other circumstances. A precise knowledge of the effects, and a correct view of all the agencies concerned, will lead us to the determination of the conditions under which the laws operated. In no other way than this has any one of the problems of organic and inorganic Nature, as we now behold her, been solved; no other process can possibly lead to real knowledge of the prior conditions of the globe. Geology can only pretend to the rank of science in proportion as it proceeds upon the principles of the Inductive Philosophy, and is aided by the advance of collateral inquiries. The history of a science is the description of its real progress; but if geology could have no existence before the phenomena of chemistry, zoology, and mechanics were studied in relation to laws of nature, its ancient history must be of small importance. Born in our own days,—based on modern observations,—interpreted by modern philosophy,—why should we seek rational geology in the monstrous systems of astronomy and cosmogony, which once satisfied Greece and Egypt? why attempt the vain task of tracing the various errors of those writers of later

days, who, knowing nothing of chemical or vital laws, and little of mechanical science, proposed hypotheses instead of collecting facts, and referred phenomena, which they had not correctly observed, to forces which they had never truly ascertained; resigned the beautiful monuments of ancient life, the fossil remains of animals and plants, to a plastic force of Nature, and attributed the regular and orderly structure of our planet to a general destruction and ruin of an earlier sphere?

PROGRESS OF GEOLOGY.

Exactly in proportion to the progress of collateral science is the dawning of geological inquiry. The improvement of mechanical science effected by Galileo and Newton opened, after a long interval, the minds of Mitchell and Saussure to a perception of the effects of great convulsions in the crust of the globe; the progress of chemical philosophy awakened, amongst the mining schools of Sweden and Saxony, these zealous efforts to develope the history of the mineral constituents of the globe which led to the Wernerian system of Geognosy; but it was reserved to modern days and more refined knowledge of natural history, to establish sound general principles of investigation concerning organic remains, and to unfold the successions of living nature, which constitute the basis of the truths established by Smith and Cuvier.

The very essence of geology, then, is such, that its conclusions can only be established in consequence of the general progress of the natural sciences; on the other hand, it makes no step without consolidating and enlarging our knowledge of existing nature; and thus it is inseparably united with the general march of the human intellect, and

supported by the sympathy of all those who look with wonder and curiosity on the visible works of God.

Those who have taken a narrow view of this great and growing branch of human knowledge, who have satisfied themselves with collecting a few fossil shells, naming a few compound rocks, and constructing a few sections and maps, may possibly be startled at the mighty circle of perpetual research in which they are unconsciously engaged; yet as, in every branch of natural science, the generalizations which are the object of inquiry can only be based on accurately ascertained facts, every one who is really employed in investigating any of the phenomena of nature, must be hailed as a useful coadjutor to geology. The time is come when enough of general truth is known in geology to direct the labours of observation into right and fertile channels; and those who are best acquainted with the actual state of the science, and most sensible of its many desiderata, will be most likely to devise the best means of supplying them. This consideration should diminish the distrust which men of exact observation feel for the researches of theorists. Theory and useful observation must proceed or be retarded together; a man who is not taught how to observe, and instructed what to observe, is just as likely to mislead by his descriptions of phenomena, as a theorist who leaves the true path of inductive philosophy, substitutes hypothesis for inference, and contends for the ideal speculation instead of working out the true law of nature.

What is possible to be known.—All human knowledge is limited; but who has reached the boundary in any direction? Doubtless there are geological problems which can never be solved, many recondite laws which can never be d'sclosed by investigation of visible phenomena;

but yet the progress of the human mind, or rather the combination and mutual irradiation of ascertained truths, continually removes farther and farther the visible barrier of knowledge, and renders possible many problems once despaired of.

The province of direct *geological* observation is limited to a small depth below the surface of the globe, and nothing but the progress of a higher science could give us any information as to the interior. But even those dark and unapproachable regions are not wholly hidden from the astronomer; some material properties of the central regions of our planet are already revealed by refined mathematical interpretation of the phenomena of the universe; and though we may never know *what* are the chemical qualities of the substances more than a few miles below the surface of the earth,—never be able, in ordinary language, to say *what sort* of matter composes the interior, yet many of its most important properties, as weight, density, temperature, may be at least partially ascertained, and their state of rest or motion, fluidity or solidity, made the subject of probable inference.

Direct observation may fail to give us complete information concerning the many previous conditions of the surface of our planet, because it is not certain that monuments remain of all the changes which have occurred, and, if they do remain, it is not probable, or possible, that we can examine them all; a minute and continuous history of the physical revolutions of the globe is therefore not to be attempted, at least for a long time to come; but, just as from the incomplete history of the human race, principles are derived which shed a clearer light on the darkness of antiquity, determine the epochs of its changes, and discover more certainly the true relative condition of the *existing*

races of men,—so the general rules of geology contribute continually to fill up the void spaces in its monumental history, to determine the amount of physical changes performed in particular geological periods, to ascertain the rate and progress of such changes, and thus to characterize the present aspect of nature by reference to many previous ascertained conditions of it.

General data.—The most important of all the data for geological theory are derived from other and very distinct branches of science. It is to astronomy and general physics that we are indebted for the establishment of some leading principles which must ever be observed in reasoning on the revolutions of the globe, and in fact form the only general basis for such reasoning. The singular prejudices which yet prevail, among good observers in geology, as to the real objects and aims of the science, apply even to the facts furnished by astronomy for the guidance of geology; and sure consequences legitimately drawn from considerations of the figure and density of our planet are often confounded, by what are called practical men, with mere speculation; and they imagine they give proof of exceeding wisdom when they reject *en masse* the independent conclusions of higher science, and the local and limited inferences from undoubted facts, as if these partial truths were mere hypotheses. Nothing is more common than to hear persons who have never qualified themselves to judge of the question, complaining of the prevailing tendency of geologists to indulge in theories; as if that most enormous and yet unattempted labour,—the construction of a general theory of the earth, was a mere morning's amusement; as if the combination of individual facts into limited generalizations, and the attempt at eliciting laws of phenomena, which in every other branch of natu-

ral science is hailed as the first proof of real progress made, should in geology alone be condemned as dangerous and delusive; as if the search after general truths, which in every other science is known to be the real object, aim, and end of the inquiry, should be in geology alone the thing of all others to be deprecated.

On the other hand, it seems no less necessary to offer a short caution to those who, seeing the great accession of local truths and partial laws of phenomena which has of late so rapidly been added to geology, are anxious to anticipate time, and think it more useful to construct a perishable hypothesis than to add to the durable foundation of theory.

Figure of the Earth.—The figure of the earth is known by direct measurement of arcs, and by experiments with the pendulum, to be a spheroid with its polar diameter about $\frac{1}{299}$ shorter than the equatorial; the former being 7899,170 miles, the latter 7925,648 miles; the difference, commonly called *the compression*, 26,478 (Herschel—*Astronomy*). This peculiar figure is a consequence of the centrifugal force of the superficial parts of the globe removed from the poles; for this diminishes the influence of gravitation, and permits the equatorial parts, where the velocity of rotation is greatest, to recede further from the axis than any other parts, till the equilibrium is obtained, and the curves over all parts of the globe correspond to a *spheroid of revolution.* The earth, then, has acquired its present figure under the joint influence of gravitation to its present centre, and rotation on its present axis; but if the mass of the globe were solid, this exact accommodation of dimensions could not take place; we must therefore add a third condition, viz. that, in some way or other, its parts must be yielding and displaceable, fluid or loose. If the globe was formerly, or is

now fluid within, wholly or in great measure, the spheroidal figure is a direct and necessary consequence, and this is the view generally adopted; but it has been imagined that even a solid globe whose superficial parts were displaceable, might, in the eternal round of natural changes, be worn down by rains and waves from a perfect sphere to a spheroid of revolution. According to this supposition the former state of the globe was very different from the present; the rotating sphere must have become very elevated land at the poles, and totally drowned in water along an equatorial band; into this equatorial sea, from the north and the south, must have been poured the waste of the high polar lands so as to form strata thickest under the equator; the slope should still be land:—but nothing of the kind appears. On the contrary, the distribution of land and water is excessively irregular, the surfaces of stratified rocks have no peculiar relation to the equator, the poles are in the midst of water, and the equatorial regions include some of the highest mountains on the globe. This hypothesis is therefore entirely gratuitous, and we must look to the interior of the earth for the displacement of substance which allowed it to assume a spheroidal figure.

Here little difficulty presents itself; it cannot be doubted that, if the interior of the globe were fluid, a spheroidal external figure must necessarily result from rotation on an axis, and the internal surfaces of equal density be also spheroidal; and both these conditions be retained whether it continued fluid or not; if it continued wholly fluid, the figure might continually adapt itself to any change of form corresponding to a variation of the ratio of central and tangential forces; if it became wholly solid, the rocks would upon such change of ratio be put in a state of strain; if

internally fluid and externally solid, the crust might upon such change yield in various directions, and produce local irregularity in the distribution of land and water: finally, if the solidification of the surface were to proceed at a certain rate, compared with that of the change of ratio of the forces governing the figure, the form once acquired might be almost invariably preserved.

Of all the conditions stated above, which corresponds best to what is known concerning the earth? That its internal surfaces of equal density, are situated symmetrically with respect to the external spheroid is supposed to be true, in consequence of investigations concerning certain irregularities of the moon's motions, which depend on the figure and density of the earth. This would prove that the earth has been freely yielding within; the irregularities of the pendulum experiments appear sufficient to justify a belief that the solidification of the surface has gone to some considerable depth; the irregular distribution of the land and water appears to indicate the co-existence of a solid crust and yielding interior, accompanied by a change of form. This irregularity of land and water is the effect of great convulsions of the crust of the globe belonging to many geological periods, some of them subsequent to the existence of the present races of animals and plants. It is therefore very probable that the interior of the globe has formerly been wholly fluid; and we are not entitled hastily to reject the supposition that it is partially so at this moment.

Density of the Earth.—Taking water at a temperature of 60° as the unit of comparison, we find the specific gravity of the superficial parts of the globe, as judged of by weighing the most prevalent rocks, to be about 2·5.

By direct experiments, and comparison of the local at-

traction of mountains and insulated masses of matter with the general attraction of the globe, the mean density of our planet has been inferred to be about five times that of water. This result is found sufficiently in accordance with astronomical considerations to allow us to adopt it for geological reasoning.

The interior parts of the globe must therefore be heavier than the exterior rocks.

From the influence of the earth on the moon's motions, it is inferred that the internal mass of our planet augments in density towards the centre; the surfaces of equal density being symmetrical with the external spheroidal surface. The materials of the earth have therefore collected round the centre in obedience to the laws of gravitation and rotatory movement, and the internal substances, as having fallen to the lower place when freedom of motion was allowed, would probably be heavier under the same circumstances than the superficial substances. In their present situation, their weight is augmented by the effects of the general pressure towards the centre; if the laws of compression observed among metals, stone, fluids, and gases, at the surface of the earth, obtained in the inner parts of the earth, without some counteracting cause, steel would be compressed into one-fourth, and stone into one-eighth of its bulk at the centre. Water, according to Leslie, would be as heavy as quicksilver at 362 miles depth, and air as heavy as water at thirty-four miles. (Somerville—*Connexion of Physical Science.*) Now, though we cannot presume that the law of compression would hold in these bodies to such an extent, enough is known to justify a confident belief that the mean density of our planet would be very much greater than it is, were not the tendency to

enormous condensation in the central masses counteracted by some powerful agent of expansion, such as heat, or neutralized by some peculiar and unknown constitution of the substances themselves.

TEMPERATURE OF THE GLOBE.

It becomes, therefore, necessary to inquire into the subject of the earth's temperature. The superficial heat of the earth's surface is subject to several known, and probably to other unknown, influences; of the known causes of variation, the following are the most worthy of the notice of geologists:—

1st, The influence of the sun.

2d, The influence of the distribution of land and water, and the nature of the surface.

3d, Elevation above the mean level of the sea.

4th, The temperature of the circumambient space.

5th, The temperature of the interior of the globe.

1. The solar rays are the principal source of heat on the surface of the globe; the temperatures vary in relation to the amount of those rays; the mean temperatures consequently decrease continually from the equator toward the poles, nearly in the simple proportion of the cosines of latitude. (Mayer's formula of the square of the cosine appears very inaccurate both at the equator and toward the poles.) At every point of the earth's surface the temperature changes with the period of the year, nearly in proportion to the variation of altitude and duration of solar irradiation: it changes also with day and night. No proposition is more certain than the fundamental dependence of the temperature of the surface of the globe on the solar influence.

It is, therefore, very important for geologists to inquire

whether this be variable or constant; whether the amount of solar heat communicated to the earth is and has always been the same in every annual period, or what latitude the laws of the planetary movements permit in this respect.

Sir John Herschel has examined this question in a satisfactory manner, in a paper read to the Geological Society of London. The total amount of solar radiation which determines the general climate of the earth, the year being of invariable length, is inversely proportional to the minor axis of the ellipse described by the earth about the sun, regarded as slowly variable; the major axis remaining constant, and the orbit being actually in a state of approach to a circle, and consequently the minor axis being on the increase, it follows that the mean annual amount of solar radiation received by the whole earth must be actually on the decrease. The limits of the variation in the eccentricity of the earth's orbit are not known; it is therefore impossible to say accurately what may have been, in former periods of time, the amount of solar radiation; it is, however, certain, that, if the ellipticity has ever been so great as that of the orbit of Mercury or Pallas, the temperature of the earth must have been sensibly higher than it is at present. But the difference of a few degrees of temperature thus occasioned, is of too small an order to be employed in explaining the growth of tropical plants and corals in the polar and temperate zones, and other great phenomena of geology.

2. Nature of the Surface.—The heating effect of the sun's rays varies with the nature of the surface on which they fall: the colour, texture, capacity for heat, and other circumstances affecting the absorbent and reflective powers of the substances, influence, accordingly, the amount of

heat absorbed and retained. The reflective surfaces of snow which cover so large a portion of the polar land, while they refuse admission to the solar heat, and contribute to warm the upper air, prevent also the dissipation of terrestrial warmth. Sandy and rocky tracts reverberate heat into the air; grassy plains and cultivated fields freely absorb heat by day, and freely radiate it by night.

Though these circumstances are little sensible in registers of annual, monthly, or diurnal temperature, they affect very seriously the growth of plants and animals, and constitute a very important character of local climate which ought to be more attended to. The large forests of equatorial regions maintain, in their ample shade, a permanent coolness, favourable to vegetation; in the temperate climates of Europe, their destruction has perhaps mitigated the periodical severity of cold. But the most important of this class of phenomena is derived from the unequal distribution of land and water upon the globe. The climate of the ocean is very different from that of the land, less extreme in its variations with season, and limited within narrow ranges over the whole watery surface. This is, in a great degree, owing to the movement of the particles of water upwards and downwards, according to the variation of temperature at the surface, and the movement of the tidal and other great oceanic currents. Thus the fluctuations of heat are not merely confined to the surface, but diffused through great depths and breadths of water, and the climates of remotest regions mixed and mutually mitigated by the beneficent movements of the sea.

On the land a similar, but less regular and continuous, influence is performed by the winds, which, by appointed laws, change and fluctuate in their paths, and cause *alter-*

nation rather than *gradation* of climate, a variable succession of different and often extreme temperatures; so that the range of variation of heat is greater at any one point on the land than in the sea, and the difference of temperature in different latitudes is greater.

The warmest band of the ocean is that running up the Atlantic; the coldest points of the globe are in the northern part of the land of Asia and America. If, instead of so much land round a polar basin, we had broad equatorial continents and small polar isles, the temperature of the globe would have been more uniform than at present; the excessive cold of the polar circles would be reduced; some slight general augmentation of heat in the polar sea might be experienced, but not so great an addition of heat as to account for the phenomena of the growth of coral in the sea, and tree ferns on the islands.

The distribution of land and water is a variable element of importance in the question of the former temperature of the surface of the globe, but its variations must not be imagined equal to cause a change of more than a few degrees.

3. Elevation above the mean level of the sea, is another important circumstance affecting local climate, and the general amount of heat on the earth and in the air about it. The atmosphere surrounding the earth is not heated by the sun's rays passing through it; it freely transmits them. Clouds, and particles of all kinds in it, must arrest some heat as it radiates from the sun or from the earth, but the main supply is derived from the earth by conduction. Near the earth, the temperature of the air seldom differs from that of the surface, whether that be land or sea; and in all the higher regions, amidst the complications of aërial currents which rather alternate than mingle, we find the

temperatures decrease as the density of the air diminishes, so that, at moderate heights, a diminution of 1° Fahrenheit corresponds to about 323 feet elevation. (Forbes.)

This settled law of atmospheric heat reacts on the elevated land, and causes a reduction of the mean temperature of the higher stations, exactly of the same nature, and as regularly calculable, as that depending on latitude.

4. Temperature of the Planetary System.—The temperature of the space surrounding the earth cannot be hotter than the coldest point on the surface of the globe: for, since the globe is continually receiving heat from the sun, and radiating it into space, the cooling process can only proceed so far as to reduce the surface temperature to an equilibrium with that of surrounding space.

The lowest temperature on the globe (Melville Island) being taken at 50° cent. below zero, we may be sure that the ethereal spaces have not a higher temperature. In fact, Fourier and Swanberg agree in adopting this as the real temperature of the planetary spaces. The opinion, daily gaining strength, of the universal diffusion of an elastic ether, renders probable the conclusion that the immense regions in which the planets move have a definite temperature; if the ether vary in density about different centres or systems, which is at least not improbable, the statical temperatures may vary also with situation; but, as far as we have yet learned of the solar system, there is no reason to imagine the temperature is sensibly variable with time; not even if the planets are continually losing heat.

5. Temperature of the Interior of the Globe.—Hitherto we have considered the globe as merely a recipient of heat from the sun, measured in quantity, and distributed in a particular manner. This heat is again partly dissipated

into the atmosphere and ethereal spaces, so that there is no superficial accumulation of heat derived from the sun: the climates on the earth appear to be constant, except by the interference of some of the variable circumstances previously adverted to.

But we must not bind our views to the surface; the state of the interior of our planet, in relation to the intensity, constancy, and circulation of the heat there, is of the greatest possible importance.

There can scarcely be found a more striking example of the beneficial influence of geology on collateral science, than the impulse it has created toward the cultivation of the curious and delicate inquiry into the theory of internal terrestrial temperature, both among mathematicians and experimentalists. What a contrast is offered by the wild speculations of Burnet and others, concerning the constitution of the interior of the globe, and the profound conclusions of Fourier, which every succeeding experiment appears to render more certain.

But for a geological necessity, so to speak, the beautiful mathematical researches of Fourier and the experiments of Humboldt, Cordier, and others, would never have been made; and even philosophers might have been content, with the uninstructed vulgar, to have no thoughts on the matter of the earth's proper heat. There is a singular prejudice on this subject, which is worth notice, as an example of the difficulties often attending the promulgation of novel truths. Some persons are startled at the very idea of the interior of the earth being hot; as if it were some monstrous and insufferable doctrine; as if it were something utterly unreasonable that the centre of a planet should be asserted to have a temperature very different from that

of its surface. Much of the declamation against central heat, as it is incorrectly termed, has no better foundation. But how is it to be known whether the exterior of the earth may be very hot or very cold, or synthermal with the surface, except by mathematical and experimental investigation, especially directed to the question? The problem certainly is difficult, but not impossible, and it is fraught with the highest interest.

It has been proved by Fourier's mathematical investigations on the theory of heat, that the temperature of the surface of our planet being, as we know it to be, wholly dependent on the solar radiation, the interior of the mass may have any temperature whatever, any extreme of heat or cold, without producing any sensible effect on the surface.

The reason of this is very simple; the conduction of heat, by the substances near the surface of the earth, is so exceedingly slow, that ages might pass before there could be any sensible warmth communicated from even intensely hot masses placed at a moderate depth.

It appears from the mathematical theory, and it is fully established by experiment, that the fluctuations of the solar heat are experienced only to a certain depth, below which the temperature of any one point is invariable; this depth is not every where the same, but, as far as yet appears, nowhere exceeds 100 feet. The temperature at this depth is constant, and generally corresponds, at least nearly, to the mean annual temperature of the surface. The temperatures below this depth can only be known by experiment. Before stating the results of these, it may be useful to advert to the simple reasoning which must be employed in drawing conclusions from them. If it be found that the temperatures below the zone of fluctuating heat continually

diminish, it is evident that the interior parts of the earth are colder than the surface, and that there is no reason to imagine the earth to have any other source of heat than solar radiation; but if the contrary be found true, the earth has a proper temperature, derived from internal sources. If the augmentation be merely a *local* phenomenon, *local* chemical action may perhaps explain it, but if it be a *general* fact, we must appeal to a corresponding general cause.

Experiments on the temperature of the interior of the globe require great attention, and must be interpreted with caution. In mines, collieries, &c., the influence of lights, respiration, &c., is considerable; in these, and almost all situations, chemical processes go on which must be considered; there are local sources of heat to be allowed for, as mineral waters, the augmented density of air, &c. Into the examination of these points it is not necessary to enter further. The reader must suppose that they have been attended to by M. Cordier, M. Arago, and others, both in selecting experiments and drawing inferences. The following examples include single and continued observations in different situations and under varied circumstances.

1. Single experiment in the deepest colliery in Great Britain at Monkwearmouth, near Sunderland, soon after the sinking of the shaft (Phil. Mag. 1834). Depth of the pit to the place of observation, 528 yards; depth below the level of the sea, 500 yards; mean annual temperature, 47.6. Observed temperature of air at surface on the day of experiment (15th November 1834), 49°—of air at the bottom of the pit, 62°—near the forehead (or end of the drift), 64°—close to the coal, 68°. Temperature of water collected in the pit bottom, 67°—of salt water issuing from

a bore hole made on the same morning, 70.1—of similar water as it first gushed out, 71.4—of gas bubbles issuing through the water, 72°.6. Temperature of the front of the coal, 68°—of the interior, 71°.¼. A thermometer left in a bore-hole for a week, indicated 71°.2.

If invariable temperature be supposed to commence at 100 feet, and the mean annual temperature of the place be taken at 47.6, then 72.6°— 47.6 = 25° in 1484 feet, or 1° F. in twenty yards English, nearly. The pit has since been sunk deeper, and the temperature is found to have risen still higher.

2. *Continued Experiments on Subterranean Springs.*

Countries	Authors.	Mines.	Depth in Feet.	Temperature obs.	Mean Ann. Temp. of Surface.	Depth for 1° F.
Saxony	Daubuisson, 1802.	Lead and silver mine of Junghohe Birk	256	48.9	46.9	102.4
		Do. Beschertglück	712	54.5	46.4	87.
		Do. Do.	840	56.8		80.7
		Do. Himmelfahrt	735	57.9		63.9
	Gairdner, 1820.	Do. Kurprinz,	634	80.1		18.8
Brittany	Daubuisson, Sept. 1802.	Do. Poullauen,	128	53.4	52.7	182.0
		Do. Do.	246	53.4		351.0
		Do. Do.	459	58.3		82.0
		Do. Huelgoet,	197	54.	51.8	89.5
		Do. Do.	262	59.		36.4
		Do. Do.	394	59.		54.7
		Do. Do.	755	67.5		48.4
Cornwall	Fox, 1821.	Dolcoath mine	1440	82.	50.	45.0
Mexico	Humboldt.	Guanaxato silver mine	1713	98.2	68.8	45.8

In a well at La Rochelle, depth 369½ feet, temperature observed, 18.12 C.; mean annual temperature of surface, 11.87 C.; depth for 1° F. 33 feet.

3. *Continued Experiments in Rock.*

Countries.	Authors.	Mines.	Depth in Feet.	Temperature obs.	Mean Ann. Temp. of Surface.	Depth for 1° F.	
First Series. In rock near the surface.							
Saxony	Von Trebra, 1805-6-7.	Mine of Beschertglück	591	52.2	46.4	101.	
		Do.	853	59.		67.	
		Do.	236	47.7		174.7	
		Do.	552	55.		63.7	
		Do.	880	59.		69.8	
		Do.	1246	65.7		64.4	
Second Series. In loose matter near the face of rock.							
Cornwall	Fox, 1821.	United copper mines	1142	87.4	50.	30.5	
			1201	88.		31.1	
	Cordier, 1821.	Carmeaux. Coal-pit of Ravin .	597	62.8	52.	55.3	
		Coal-pit of Castellan	630	67.1	52.	40.8	
		Littry. Coal-pit of St Charles .	325	61.		36.1	
		Decise. Coal-pit of St Jacobi .	351	64.		29.2	
		Do.	561	71.7		28.5	
Third Series. Three feet three inches in the rock.							
Cornwall	Fox, 1820, Register kept for 18 months.	Dolcoath .	1381	75.6	50.	54.	Variation.
Saxony	Reich. Oct. 1829 to Oct. 1830.	Lead and silver mine of Kurprinz .	18	51.8 to 46.4			15.8
		Do.	413	59.6		31.3	3.3
		Do.	686	62.5		42.6	0.2
		Do.	1063	67.7		49.9	1.0

4. *Artesian Wells* (*by M. Arago*).

	Cent.	Metres deep.	Diff. of Temp.	Metres to 1° C.
Paris.				
Mean temperature of the surface, .	10.6			
Fontaine de la Garde St Ouen .	12.9	66	23.	29.0
Dept. du Garde et des Pàs de Calais.				
Mean temperature of the surface,	10.3			
Fontaine Artesienne de Marquette,	12.5	56	22.2	25.5
Fontaine Artesienne d'Aire, .	13.3	63	3.	21.
Fontaine Artesienne de St Venant,	14.0	100	37.	27.
Sheerness, at the mouth of the Medway.				
Mean temperature of the surface, .	10.5			
——— of the deep well,	15.5	110	5.	22.
Tours.				
Mean temperature of surface, .	11.5			
——— of Artesian Well,	17.5	140	6.	23.3

Mean result of the six observations, 24.6 metres to 1° C.
— — — — 13.66 metres to 1° F.
— — — — 45 feet to 1° F.[1]

The results from artesian wells, the water being pure, are probably as much to be depended on as those from mines: it is remarkable that the two classes of results coincide, for Monsieur Cordier's previous conclusion from the latter phenomena is, that the temperature augments one degree of Fahrenheit in forty-five feet English. The ratio is, however, certainly not uniform at different places, as might be anticipated from the unequal conducting power of the rocks.

It appears, then, fully ascertained, that, in situations far removed from volcanic action, in different kinds of rocks with very different chemical relations, water, air, and rocks continually grow warmer as we descend in the earth. *Without a single exception*, the interior of the globe is warmer than the surface, and the heat augments constantly with the

[1] See *Annuaire*, and *Jameson's Journal*, 1825.

depth. Combining this result with the mathematical inferences of Fourier, and the generalizations concerning the state of the central parts of the globe, we shall find that it is not without reason the distinguished mathematician above named has favoured the hypothesis that the earth is a cooled globe, very hot within, and still cooling slowly; so slowly, indeed, that the effects of the contraction due to this refrigeration have not been perceived by astronomers in the alteration of the length of the day, which must inevitably have occurred if the diameter of the globe had sensibly diminished. For all short periods of time, that is, for a thousand or two thousand years, the globe may now be supposed to be in a statical condition, both as to interior and superficial heat, magnitude, and figure.

The hypothesis of a cooling globe, thus brought fairly under our notice, can only be changed into theory by its accordance with geological phenomena of very ancient date, which can in no other way be so well explained.

DEPTH OF THE OCEAN.

A knowledge of the probable depth of the ocean is of importance in limiting the range of some speculations in geology. In questions concerning the relative areas of land and water, and the change of level of land and sea, it is desirable to have some notion of the quantity of water on the globe. Its area we know, but its mean depth is uncertain. Laplace and the astronomers appear to be satisfied with believing that the depths of the sea balance the elevations of the land; so that the extreme depths may not be very great, and the mean depth only a small number of miles. If we were to suppose the depths of the sea proportioned to the heights of the land, in the ratio of the

respective areas, and similar inequalities of level to prevail, the greatest depths might be taken at about fifteen miles, and the mean depth would not exceed from one to five miles, according to the supposed form of the oceanic bed.

From the investigations of Mr Whewell on the velocity of the tide-wave (Phil. Trans.), some exact knowledge on this subject is already gathering for geology. According to the supposition of Lagrange, this velocity is a function of the depth of the channel, without regard to other conditions; the velocity is in fact that which a heavy body would acquire by falling through half the depth. According to this view, the depth of the sea on the east coast of England is 120 feet, on that of Scotland 360 feet, of the Atlantic coast of Ireland 2600 feet, of the Atlantic (in its middle part) 50,000 feet, or above nine miles. These depths, judging from the soundings on the east coast of England, are good approximations; and inspection of Mr Whewell's maps of the cotidal lines seems to forbid our imagining the sea to be any where for great breadths very much deeper than the Atlantic.

On this subject Mrs Somerville observes,—"The sea has little influence on the variation of the length of the arcs of the pendulum or on gravitation, neither does it much affect the lunar inequalities. The mean depth of the ocean is very small. There may be profound cavities in the bottom of the sea, but its mean depth probably does not much exceed the mean height of the continents and islands above its level."—*(Connexion of Phys. Science.)*

EXTENT OF THE ATMOSPHERE.

The quantity of gaseous matter floating above the earth is known by direct weighing with the barometer; analysis

resolves this airy ocean into its constituent elements, and shews us the proportions of oxygen and nitrogen, which, with carbonic acid, aqueous vapour, and other variable admixtures, make up the whole mass. Is the quantity of the atmosphere constant? its composition invariable? or what are the sources and limits of variation? In the present state of meteorology these questions admit of no satisfactory answer. It is true that, within the short period of barometric measurement, no phenomena have given reason to suppose any alteration of atmospheric pressure, and that, in every case of well conducted analysis, the atmosphere has every where and always been found similarly constituted. But when we know by how many operations the air is decomposed, fixed, and released in chemical and vital combinations, how much gaseous matter is daily poured from the earth into the air, it is clearly beyond our power to affirm that the quantity and quality of the air may not be now undergoing a slow and determinate change. If study of the planetary bodies of our system appears to shew that atmospheres are not necessary accompaniments of such bodies, how can we feel confident that our own atmosphere must ever retain one peculiar quality and quantity? It is evidently possible that the sources of variation which are daily in action may not exactly reciprocate their influence, or if they do now (which no one can affirm), who shall prove to us that they have always done so? or rather, who that considers the composition of the most abundant rocks in the crust of the globe, and remarks the immense quantity of oxygen contained in them all, even to the half of their weight, can avoid imagining the liberation of that gas, and a corresponding enlargement and chemical change of the atmosphere? We cannot, however, philosophically assume

that the atmosphere is changeable in quantity or quality, except in virtue of well founded inferences from phenomena pointing specially to such a supposition. A case supposed to be of this description will hereafter come under discussion.

If the dimensions of the earth or the mean temperature of its surface have been changed, the quantity and quality of the atmosphere might remain the same, and yet its vital effects would be greatly altered.

GEOLOGICAL DATA.

Materials of the Globe.—The solid substances composing the external parts of the globe, with which alone we can become acquainted by specific observation, may be considered in several points of view, according to the object of the reasoning; but for the fundamental researches of geology, they may be all subjected to the following process or formula.

Rocks, or very considerable component masses of the globe, are composed of particular *mineral substances*, which are resolved by chemical analysis into their *proximate constituent parts*, these being further resolvable, in many instances, into *elementary or undecomposable molecules.*

Some rocks are simple, that is, composed of one kind of mineral substance, as limestone; others compound, or formed of two or more kinds of minerals, as granite; some rocks, apparently simple, as certain kinds of slate, sandstone, &c. are really composed of several minerals, minutely and equally mixed. In this respect the nomenclature of geology (and mineralogy in a less degree) is not always accurate. As examples of the processes whereby we record these dif-

ferent characters, we may place in the same table granite and limestone.

Names of the Rock.	Names of the Mineral Ingredients.	Their Proximate Constituent Parts.	The Elementary Constituents.
Granite.	Quartz.	Silica.	Silicium + oxygen.
	Felspar.	Silica.	Silicium + oxygen.
		Alumina.	Aluminum + oxygen.
		Potash.	Potassium + oxygen.
		Lime.	Calcium + oxygen.
		Oxide of Iron.	Iron + oxygen.
	Mica.	Silica.	Silicium + oxygen.
		Alumina.	Aluminum + oxygen.
		Magnesia.	Magnesium + oxygen.
		Oxide of Iron.	Iron + oxygen.
		Potash.	Potassium + oxygen.
Limestone.	Limestone.	Lime.	Calcium + oxygen.
		Carbonic Acid.	Carbon + oxygen.

It is found that nearly all the solid, liquid, and gaseous substances which occur in or upon the globe in a natural state are compound; particular metals occur pure in nature, other substances, especially gaseous matter, are rendered so for a short time by vital and chemical operations; but it is a fact that about half the ponderable matter of those parts of the globe which we are acquainted with by exact observation, is composed of oxygen.

In the present temperature and pressure of the atmosphere, oxygen can only exist separately as an expanded gas, about $\frac{1}{800}$th part of the weight of water; but in the solids and liquids of the crust of the globe it is condensed to an astonishing degree. In water, it is joined with the light gas hydrogen, condensed 2000 times, and in the same or a greater proportion in the oxides of metals.

The consideration of the laws regulating the combination of the elementary and proximate constituents belongs

to CHEMISTRY; the study of the inorganic compounds thus formed constitutes MINERALOGY; the history of the great masses of mineral substances which enter into the crust of the globe constitutes the principal or fundamental part of GEOLOGY, which, however, cannot be completely investigated without including many general considerations arising from the former branches of knowledge.

There are fifty-four substances known to chemists which have never been proved to be compound, and are, therefore, provisionally ranked as elementary sorts of matter. Of these, five, when they occur in a separate state (in the ordinary temperature and pressure), are in the state of gas, viz. hydrogen, oxygen, nitrogen or azote, chlorine, fluorine. Five are volatile non-metallic bodies, viz. bromine (fluid), iodine, sulphur, phosphorus, selenium. Two are fixed (or incapable of being volatized) non-metallic bodies, viz. carbon, boron. The remaining substances are metallic or metalloidal. Seven of them are earthy metals or metalloids, which, by combination with oxygen, yield the earths, viz. silicium, aluminum, magnesium, yttrium, glucinum, zirconium, thorium. Six are alkaline metals, yielding alkalies with oxygen, viz. potassium, sodium, lithium, calcium, barium, strontium. Fifteen are metals which retain oxygen at high temperatures, viz. lead, tellurium, copper, bismuth, titanium, cobalt, cerium, uranium, antimony, columbium, tungsten, chromium, vanadium, molybdenum, arsenic. Nine are metals which part with oxygen at high temperatures, viz. mercury, silver, gold, platinum, palladium, rhodium, iridium, osmium, nickel. Five absorb and retain oxygen at high temperatures, and decompose water at a red heat, viz. tin, iron, zinc, cadmium, manganese.

Most abundant substances.—The most abundant (and

on that account the most important to the geologist) of the elementary substances enumerated are oxygen, hydrogen, chlorine, sulphur, phosphorus, carbon, silicium, potassium, sodium, calcium, magnesium, aluminum, iron, manganese.

Most abundant minerals.—The minerals formed by the combination of the several ingredients among one another are doubtless very numerous; already several hundred species have been recognised, but of these many are exceedingly rare, and others occur only in particular situations, so that the principal rocks of the globe are formed of only a small number of mineral substances. The geologist is not absolutely required, except for particular trains of reasoning, to be an accomplished mineralogist; but it seems unwise to countenance the neglect of mineralogy, which appears to have become not unusual among those who have been foremost to cultivate the zoological principles of geology. We must not grant to the lovers of organic remains that a person may be too good a mineralogist to be a good geologist.[1]

It will be scarcely possible to make any useful progress in examining or describing rocks, unless the student is able to recognise and distinguish the following minerals.[2]

Quartz,	Green earth,
Felspar,	Talc,
Mica,	Steatite,
Hornblende,	Garnet,
Actynolite,	Carbonate of lime,
Augite,	Carbonate of magnesia,
Hypersthene,	Sulphate of lime,

[1] See on this subject Whewell's *Report on Mineralogy to the British Association*, 1832.

[2] See Jameson's *Mineralogy*, MacCulloch *on Rocks*, Phillips' *Guide to Geology*, &c.

Diallage,	Chloride of sodium,
Schorl,	Bitumen,
Chiastolite,	Iron, oxide of,
Chlorite,	... sulphuret of,

Supposing that at least some knowledge has been acquired of these substances, the student of geology may quickly obtain the power of recognising and discriminating the following simple and compound earthy masses (commonly called rocks), which are selected as being of frequent occurrence in the crust of the globe.

Limestone, including crystallized, compact, chalky, volatile, earthy, &c. calcareous rocks,	Shale,
	Slate,
	Chert,
	Flint,
Sandstone,	Coal,
Clay,	Ironstone,

Granite,	Felspar rock,	all locally porphyritic and amygdaloidal.
Sienite,	Claystone,	
Melaphyre,	Hornstone,	
Greenstone,	Pitchstone,	
Wacke,	Gneiss,	
Basalt,	Mica schist,	
Hypersthene rock,	Chlorite schist,	
Diallage rock,	Quartz-rock,	
Serpentine,	Hornblende schist.	

Construction of the Crust of the Globe.—It cannot with truth be said that the arrangement of materials in the crust of the globe has ever been entirely unknown, because the operations of mining, however ignorantly begun and conducted, must infallibly have led to correct, though very

limited, information concerning it. No considerable mining region in the civilized world has ever been visited by geologists where the structure of the metalliferous mountains has not long been partially known. What geologist has been able to add to the knowledge of this kind possessed by the old miners of Aldstone Moor? In what coal district have the workmen been found wholly ignorant of the succession of the sandstones, shales, and coal in which their operations are conducted?

The great step made by modern geology has been, to unite this scattered information into general truths; and it appears unnecessary to go farther back than to Werner for the proposal of correct views on this subject in Germany; to Saussure in Switzerland; and Smith in England.

In the latter country, it is true that Mitchell had made some correct researches, more general than could be expected at the period, and Whitehurst shewed himself possessed of enlarged views; but it is undoubtedly to Werner and Smith that the modern system of geology, founded on correct observations of the arrangement of rocks, owes its rapid advances.

The essential principles admitted by both these eminent men are very simple; they affirm that the materials in the crust of the globe are generally stratified, and that the strata succeed one another in a particular order or series. This is nothing more than asserting generally what is in very many instances found to be true locally by the experience of miners, colliers, well-sinkers, quarrymen, and others.

For the purpose of shewing more clearly the state of knowledge on this fundamental point, we shall suppose five independent observers engaged in inquiring into it, with

all the aids of local knowledge furnished by mines, collieries, and other excavations made by men, and abundance of cliffs, ravines, and mountain slopes where nature displays her works. One of them may be situated in the vicinity of London, another in Oxfordshire, another in Yorkshire, a fourth in the region of the English lakes; a fifth in the Highlands of Scotland.

Neglecting the variable and irregular covering of soil, gravel, sediment from rivers, &c.; the deep wells, and other excavations in the neighbourhood of London, will prove to the first observer that similar materials lie below the surface for a considerable breadth of country, that they are stratified or collected into masses which have a very great horizontal extension, and small comparative thickness; that, taken on a great scale, the series of beds is reducible to three leading terms, thus:—

Great clay of London and the vicinity at the top.
Series of sands and clays of different kinds in the middle.
Chalk at the bottom.

The Oxfordshire observer in the same manner finds that the rocks of the county are all stratified, or widely extended in nearly horizontal masses, and laid one upon another, so that the following is a general type of the series, including some parts of Warwickshire:

Chalk at the top.
Clay and sands.
Oolitic limestones, clays, and sands.
Blue clays, blue limestones, &c.
Red clays, and red sandstones at the bottom.

The Yorkshire observer finds the rocks stratified, of definite thickness, and lying in the following order:

Chalk at the top.
Clays.
Oolitic limestones, &c.
Blue clays and limestones.
Red clays and red sandstones.
Magnesian limestone.
Coal with sandstones and shales.
Limestone, &c.
Argillaceous slate rocks at the bottom.

In the district of the lakes, the stratification of some rocks is certain, of others obscure, and some are not stratified. The series of the stratified rocks, ascertained with great difficulty, is thus recorded:

Red clay and sandstone.
Coal, &c.
Limestone, &c.
Slate-rocks.
Limestone.
Slate rocks.
Red argillaceous rocks.
Slate-rocks.
Gneiss and mica schist.

Below all these is granite, which does not appear to be stratified.

Finally, the observer in the Highlands finds it often difficult to say whether the rocks are wholly, partially, or not at all stratified. After infinite labour, he decides that some are, and others not. The series of predominant stratified rocks is,

Red conglomerate and sandstone,
Argillaceous slate.

Chlorite schist, &c.
Mica schist, &c.
Gneiss, &c.

And under these is granite, which nowhere appears to be really stratified.

Thus we have two classes of rocks, stratified and unstratified, which will require distinct examination.

STRATIFIED ROCKS.

In each of the localities specified, the series of strata is found to be constant, not that every particular stratum is everywhere observed; but the *order in which they succeed one another when present together, is never reversed.* This is consistent with all experience.

It is found by actual observation, that the chalk, which is the lowest mass of strata noticed in the vicinity of London, is continuous with, and forms a part of, that chalk which is at the top of the Oxfordshire series. It is also found that this same chalk is actually traceable, with little interruption, in a very clear and satisfactory manner, from Oxfordshire into Yorkshire, where also it forms the top of the section; that the oolitic rocks, the blue clays and limestones, the red clays and red sandstones are in the same way continued from Oxfordshire to Yorkshire. The same stratified rocks then occur in very distant situations in the same order of succession, having certain rocks above them. If, now, we compare the Yorkshire and Cumbrian, and afterwards the Cumbrian and Scottish series of rocks, we shall find several common terms in similar parts of the series, and thus be able to unite all the five sets of observations into one general view.

The continuity of the strata near the surface of the

earth, and the constancy of their order of succession being thus shewn to be capable of exact proof, we may suppose not five but many thousand points and lines in the surface of the British islands to have undergone a scrupulous examination, with a view first to test the laws, and afterwards to exemplify their application. In consequence, they are unequivocally established, and the following is a general arrangement of the groups of strata, discovered in the British islands, proceeding from the surface downwards. It is supposed that all the alluvial and detrital covering of the surface is removed.

Table of British Stratified Rocks.

Names of Formations or Groups of Strata.	Thickness in yards.	Subdivisions adopted.	Remarks.
		TERTIARY STRATA.	
Crag,	16	Upper or red crag.	Shells, pebbles, sand, &c.
		Lower or coralline crag,	Shells and corals in sand or limestone.
Fresh-water group,	33	Upper fresh-water beds,	Fresh-water shells in marl or limestone.
		Estuary marls,	Estuary shells in marl.
		Lower fresh-water beds,	Fresh-water shells in marl or limestone.
London clay,	200 to 600	London clay,	Shelly clay with Septaria.
		Plastic clay and sands,	Coloured sands and clays, with or without shells.
		SECONDARY STRATA.	
		Cretaceous System.	
Chalk,	200	Upper chalk,	Soft, with flints.
		Lower chalk,	Harder, with or without flints.
		Chalk marl,	Soft argillaceous beds.

Names of Formations or Groups of Strata.	Thickness in yards.	Subdivisions adopted.	Remarks.
		Cretaceous System—Continued.	
Green-sand,	160	Upper green sand,	Fossiliferous, often chalky.
		Gault, . .	Blue marl or clay, fossiliferous.
		Lower green sand,	Often ferruginous, fossiliferous.
		Oolitic System.	
Wealden, .	300	Weald clay, .	Clay, with fresh-water shells.
		Hastings sands,	Sandstone, with plants, &c.
		Purbeck beds, .	Clay and limestone, with fresh-water shells.
Upper or Portland oolite.	100 to 200	Portland oolite,	Limestone, often cherty and fossiliferous.
		Sand, . .	Sand.
		Kimmeridge clay,	Blue clay, with shells.
Middle, or Oxford oolite, .	150	Upper calcareous grit, . .	Sandstone, often shelly.
		Coralline oolite,	Shelly oolite and coral beds.
		Lower calcareous grit, . .	Shelly sandstone.
		Oxford clay, .	Clay, with shells and septaria.
		Kelloways rock,	Sandstone, with shells
Lower, or Bath Oolite,[1] .	150	Clay, . .	Generally with few shells.
		Cornbrash, .	Coarse shelly limestone.
		Sand . .	With concretionary sandstone.
		Forest marble, .	Shelly limestone.
		Clay, . .	Thin blue clay.
		Bath oolite, .	Shelly compact and sandy oolite.
		Fuller's earth, .	Calcareous and argillaceous beds.
		Inferior oolite, .	Shelly and oolitic.
		Sand, . .	Shelly calcareous sand.

[1] This series is from near Bath. In Yorkshire and Sutherland it is different, as will be stated hereafter.

Names of Formations or Groups of Strata.	Thickness in yards	Subdivisions adopted.	Remarks.
		Oolitic System—continued.	
Lias, . .		Upper lias shale,	Blue clay or aluminous shale, shelly.
		Marl-stone, .	Sandy limestone, &c., shelly.
		Middle lias shale,	Blue clay or shale, shelly.
		Lias Limestones,	Blue and white compact limestone, shelly.
		Lower lias shale,	Coloured clays and marls.
		Red Sandstone System.	
New Red Sandstone,	300	Variegated marls,	Contain gypsum and rock-salt, shells rarely found.
		Variegated sandstones, . .	Red, white, &c. sandstones, no shells.
		Conglomerate, .	Pebbly sandstone.
Magnesian Limestone,[2]	100	Knottingley limestone, . .	Thin-bedded close-grained limestone, with few shells.
		Gypseous marl, .	Red and white clays.
		Magnesian limestone, . .	Yellow, with local deposites of shells.
		Marl slate, .	Laminated calcareous rocks.
		Rothetodteliegende,	Red sandstone, with plants.
		Carboniferous System.	
Coal, . .	1000	Upper, . . Middle, . . Lower, . .	All consisting of sand stones, shales, &c. with beds of coal, layers of ironstone, and deposites of plants.
Millstone grit,[3]	300	Upper, . . Middle, . . Lower, . .	Coarse and fine sandstones, shales, coal, ironstone, &c. with plants and shells.

[1] As it occurs in the North of England. [2] As in Yorkshire, &c.

Names of Formations or Groups of Strata.	Thickness in yards.	Subdivisions adopted.	Remarks.
Carboniferous System—continued.			
Carboniferous Limestone,[1]	600	Yordale rocks,	Limestones, grits and shales, with coal, &c. and shells.
		Scar limestone,	Very thick limestone, shelly.
		Alternating red sandstones and limestones with coal, &c.	In the north of England.
Old Red Sandstone,[2]	100 to 3300	Conglomerates and sandstone, . Coloured marls and cornstones, . Flagstone beds,	A locally variable series of rocks, fossiliferous in the south of England.
PRIMARY STRATA.			
Silurian System, as it occurs on the border of Wales.			
Ludlow Rocks,	660	Sandstones, .	Argillaceous sandstone, shelly.
		Limestones, .	Shelly and coralloidal.
		Shale, . .	
Wenlock Rocks, .	600	Limestone, .	Abounding in zoophytes, trilobites, &c.
		Shale, . .	
Caradoc Rocks,	830	Shelly limestone, Shelly sandstone, &c.	
Llandeilo Rocks,	400	Calcareous laminated beds, .	With trilobites, &c.
Grauwacke System, as it occurs in Wales.			
Plynlymmon Rocks,	unknown		Hard, slaty, fine or coarse grained rock, with few or no organic remains.

[1] As in the North of England. [2] As in Herefordshire.

Names of Formations or Groups of Strata.	Thickness in yards.	Subdivisions adopted.	Remarks.
Grauwacke System as it occurs in Wales—continued.			
Bala limestone,	unkn.		Dark, laminated, slaty limestone, with fossils.
Snowdon rocks.	unkn.		Hard slaty rocks, with (locally) few organic remains.
Clayslate System, as it occurs in Cumberland and Westmoreland.			
Clay-slate, .	unkn.		Softer slaty rocks. No organic fossils.
Chiastolite slate, .	unkn.		The same, with chiastolite. No fossils.
Hornblende slate, .	unkn.		The same, with hornblende. No fossils.
Mica-schist System.			
Chlorite schist, with limestone,	unkn.		Quartz-rock, &c. No organic remains.
Mica-schist, with limestone, .	unkn.		Quartz rock, &c. No organic remains.
Gneiss System.			
Gneiss, with limestone,	unkn.		Quartz rock, mica-schist, &c. No organic remains.

In the preceding table several terms have been employed which it will be necessary to explain. The whole mass of known stratified rocks is conceived to be divided into three great portions, called Primary, Secondary, and Ter-

tiary, from the respective eras of their production: the lowest being the oldest or earliest, the uppermost being the newest or latest. These great portions are again subdivided into systems or assemblages, named from the most characteristic kinds of rock in each; cretaceous from chalk, oolitic from oolite, carboniferous from coal, &c. or else from locality, as silurian system. The systems are composed of formations, or groups of stratified rocks, proved to have many characters in common, so as to indicate many analogies of origin; thus the chalk formation is obviously of one general type, the green sand formation contains repetitions of green and irony sands and clays, the oolitic formation is a series of oolite, sandstone, and clay in many repetitions; and so of the others.

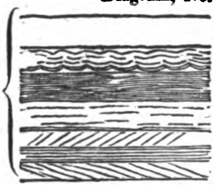
The subdivisions of formations are not established upon similar principles in all cases; the general character of them ought to be to include each one stratified rock, as the coralline oolite, or one series of alternations of particular strata, as purbeck beds, lias limestones, variegated marls, &c.

Upon this principle all the formations of the carboniferous and other lower systems should be more subdivided; but this must be left to time, and not rashly attempted without sufficient data.

Each of the stratified rocks or series of alternations thus constituting subdivisions of formations contains one or many strata, layers, or beds; the Bath oolite, the magnesian limestone, &c. are formed of many strata or beds; and so of the others. Nor is this the last term of the analysis; for many strata, as sandstones especially, are composed of parallel laminæ, which are often separable, and bear the same relation to the stratum that this bears to a stratified rock.

Diagram, No. 1.

FORMATION OR GROUP OF STRATA.



Bed without laminæ.
Bed with waved laminæ.
Finely laminated rock.
Coarsely laminated.
Obliquely laminated.
With parallel laminæ.
Obliquely laminated.

SCALE OF STRATA IN OTHER COUNTRIES.

The series of strata classed in the preceding table is always recognisable, wholly or partially, in every part of the British islands; that is to say, the stratified rocks occurring in any situation can be referred to their respective types in the general table. But the local variations are considerable; several of the stratified rocks are only of limited extent; even whole formations, as the oolitic formation, change their characters, or, as the millstone grit, are entirely extinct in particular regions where the groups above and below them are complete.

This being the case, it is evident that such subdivisions are too minute and variable to be employed in comparisons between British and foreign series of strata. We must be satisfied with comparing formations and systems, and in some cases omit even these and look only to the succession of primary, secondary, and tertiary classes of rocks.

This examination has been made in almost all parts of the world, nowhere, indeed, except in Europe and certain portions of the other continents completely, yet everywhere sufficiently to establish the truth of the following propositions.

1. The series of British strata represents very well the succession of stratified rocks in Europe, parts of Africa, Asia, and North America; this agreement is most strict

in those parts which are nearest to the British islands, and becomes more vague and indefinite as the distance increases. In France and Germany, for instance, as far as the Pyrenees and the Alps, not only the greater divisions, but nearly all the formations, most of the smaller groups, and many of the particular rocks, are well exemplified. Round the shores of the Mediterranean analogies to the same type continually present themselves. In the basin of the Indus and on the slopes of the Himalaya Mountains some of the secondary strata of Great Britain have been recognised. What is known of Australia offers less exact analogies of the same kind. In North America not only are secondary and tertiary strata known corresponding in general characters to those of Europe, but several of the European formations have been satisfactorily identified.

2. In all parts of the globe where a considerable extent of country has been surveyed stratified rocks have been found; but many small portions of the terrestrial surface are devoid of them. Stratification is, therefore, not an universal, but yet it is the most general form in which the rocky materials of the globe are accumulated.

The three great divisions of stratified rocks appear to hold the same relative position in all parts of the globe. In very distant localities the successive formations are identical, similar, or analogous, and it is evidently not unreasonable to expect from the union of observations, conducted upon one general plan, that a general history may at last be formed of all the stratified rocks in the crust of the globe, and according to the relative periods of their production.

The unstratified rocks of Great Britain, though numerous and individually variable, can yet be generally refer-

red to a few leading divisions, according chiefly to their constituent minerals. This classification will be given hereafter; we shall now content ourselves with noticing two predominant groups of these rocks, remarkably contrasted in the circumstances of their occurrence—granitic and basaltic rocks—the former lying in great masses below all the strata, frequently in the centre of a mountain district; the latter occupying fissures in them or spreading irregularly over their surface.

Few parts of the globe except some of its vast plains and deserts are entirely deficient of rocks which are not stratified, though the surface which they occupy is not nearly so great as that covered by the strata. Granitic and basaltic rocks compose generally the greater portion of the unstratified masses, as in Britain, and lie in the same relations to the strata. For granitic rocks, throughout the globe, are the most frequent axes or centres of mountain groups, and basaltic rocks fill dykes and spread in irregular cappings over the strata. It is evident, therefore, that the structure of the exterior parts of the globe, though full of local diversity, is all formed upon one general plan, and produced by similar agencies.

GENERAL VIEW OF THE STRUCTURE OF THE CRUST OF THE GLOBE.

An observer stationed on any of the widely extended plains, which occupy so large a proportion of the surface of the earth, finds, beneath the soil and loose materials, the different rocks almost universally stratified, lying in a settled order of succession, and nearly horizontal, or gently inclined in some one direction.

On the other hand, the high mountain districts generally

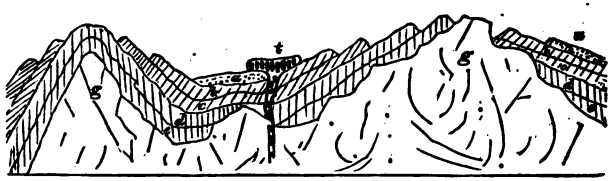
exhibit in the central points, or along their axes, granitic and other unstratified rocks under all their strata, which slope away on all sides at high angles of inclination, descend to lower and still lower ground, and finally pass under the plains and more level regions, and are there covered up and buried under other superimposed strata. Very few parts of the world offer real exceptions to this general statement. The narrow mountain chains and groups occupy far less space than the wide plains which they divide, and were the surface of the continents lowered only a thousand feet, most of them would form small islands in prodigiously wide seas. Yet they are really connected together, and all united into one system beneath, both by the unstratified rocks of the axis, and the strata of the slopes.

Let the diagram (No. 2.) be supposed a section through two mountain ranges and one intervening plain; it will be seen that the sloping strata of each mountain group are continued beneath the plain to unite with those on the other side; the strata lying in the lower countries are higher in the scale than those which rise against the mountains, and thus it happens that a person proceeding from low regions towards high districts finds strata which lay deep below gradually and successively emerge towards the mountains, and the lowest of all rise to form the highest crests and loftiest ridges. Hence also it happens that the strata are seldom quite horizontal, but generally have an inclination depending on some mountain axis. Hence also the term basin, so much used in geology, to express the sloping of strata in several directions toward a centre, a circumstance which seldom happens unless the country also agrees in geological features with the basin of the hydrographers. To discover in the plain countries the strata of

the mountains, we must penetrate the earth by deep pits; but man's power is soon limited in this direction, and a much easier method is at hand for obtaining the complete section of strata existing together in any one great geological basin.

Proceeding from the point where the uppermost stratum is found, towards the borders of the basin, the country rising gradually or by undulations, the strata *a*, *b*, *c*, &c. coming out successively, may be successively examined and measured, and a section be drawn representing the whole series, till we reach the axis of the mountains composed of unstratified rocks *g*, visible in one mountain ridge, but covered in another.

Diagram, No. 2.



In this diagram, the stratified masses *ed* may be conceived to be primary strata, *cb* secondary, and *a* tertiary; *t* may shew one of the irregular overlying masses of basaltic and some other rocks. The reader will understand from this, how it happens as a general rule that the lowest strata rise to the highest ground, and the contrary.

In comparing the sections of different geological basins, a very striking general similitude prevails, but differences perpetually occur; the whole may be reduced to one general law. The lowest or primary strata, in all the mountain ranges, and throughout all the basins of the globe, have very much of a common character; gneiss, mica schist,

clay-slate, quartz rock, with few or no organic remains, are the most characteristic strata of every country.

The secondary and tertiary strata, recurring mostly in lower ground, every where exhibit very similar chemical and mineralogical characters: they are composed of limestone, sandstone, and clay, with abundance of organic remains; but in distinct regions, the formations in which they naturally group themselves are rather analogous than closely related. The primary strata are the effects of almost universal agencies, accompanied by very similar local conditions; those of later date also agree in some general features, but exhibit diversities of character apparently due to diversity of local circumstances. In this sense, the primary deposits are almost universal, those of later date are more local and limited.

Origin of the Stratified Rocks.—That the stratified masses of the globe, resting upon one another in a settled order of succession, have been deposited from water in the same order as we now see them—the lowest first—the uppermost last—is a proposition so fully and freely admitted, that it may seem unnecessary to adduce arguments in its support; but the facts which prove the watery origin of the strata open at the same time a great variety of other truths, and disclose so clearly the history of many great physical changes on the globe that a full examination of them is essential to the acquisition of right fundamental views in geology.

Nature of the Rocks.—Viewed generally, the most abundant stratified rocks may be referred, according to their chemical constitution, to one of three great groups, viz. Siliceous rocks, Siliceo-aluminous rocks, Calcareous rocks.

The secondary and tertiary series of strata consist prin-

cipally of alternating strata of these qualities, and the same is less obviously true of the primary strata. If we consider on what mineralogical characters this general result depends, we find the siliceous rocks have almost universally a preponderance of the mineral quartz; the siliceo-argillaceous rocks consist of quartz with distinct or indistinct admixtures of felspar, mica, chlorite, or other minerals, containing alumina. Distinct mixtures of these minerals occur both in the primary and later classes of strata, but there is a great difference in the appearances of the compounds. Gneiss, mica-schist, &c. in the primary series, have very much the air of crystalline aggregation; the secondary and tertiary sandstones are clearly mechanical aggregates; yet upon more close scrutiny, this difference diminishes or vanishes. Several sandstones are almost crystalline, the particles of gneiss are really fragmentary; in both the parts are truly crystallized as to the interior texture, but in neither of them entirely free from the effects of some mechanical movement. The mica of gneiss is not often perfectly hexagonal as in granite, the quartz has generally lost its exact prismatic shape, the felspar its prominent angles. Exceptions to this occur certainly, but it is quite true as a general rule, and when fully investigated leads to a positive conclusion that nearly all the noncalcareous primary and secondary strata have been subjected, but in very different degrees, to mechanical agencies, like those concerned in the accumulation of common sandstone. Now the least examination of sandstone rocks, and comparison of them with the sandy and argillaceous deposits from rivers, in lakes, and on the borders of the sea, leaves no doubt that they have experienced the agitation of water; in fact, that they were sedimentary deposits.

Some limestones do and others do not yield evidence of similar agitation; they are often to be considered as aggregations of particles of carbonate of lime, slowly collected from chemical precipitation in water.

ORGANIC REMAINS IN THE STRATA.

The contents of many of the stratified rocks leave no doubt of their watery origin, and inform us besides of many circumstances concerning the condition of the waters. We find almost all the tertiary and secondary strata, and some (the upper portions) of the primary strata, rich in organic fossils of the animal and vegetable kinds; some, as zoophyta, crustacea, and mollusca, abound in particular rocks, so as to form a large part of their substance. Examined with care and all the advantages of modern science, marine, freshwater, and terrestrial plants and animals are found disposed with great regularity in the different strata, just as at the present day we find in the sandy bed of the sea and in lakes, the shelly remains of the marine and freshwater mollusca, and other creatures; and, scattered amongst them or lying distinct, some of the vegetable spoils of the land.

If we had witnessed the elevation of a part of the bed of the sea or a lake, by the force of an earthquake, and wished to remove any doubt in the minds of those who had not seen it, should we not triumphantly appeal to the presence of marine exuviæ in the one, and lacustrine shells in the other, for confirmation of the statement? Would not the argument be equally strong, the fact of the former submersion of one part under the sea, and of the other under fresh water, equally certain, from this circumstantial evidence alone, a hundred years after the occurrence?

This is the reasoning employed in modern geology: we find the greater part of the strata composing the known portion of the crust of the globe, full of the remains of marine exuviæ, exactly as we should find the stratified bed of the sea at this day filled with the exuviæ of now existing or lately perished animals, and we conclude, without hesitation, that the strata were deposited in the sea when the earth was in some different condition; that in fact the whole terrestrial surface of the globe was formed under water, and has since been laid dry by some natural process. Upon this clear and impregnable basis rests the whole of geological science—this is the first of its grand and impressive truths. Derived from observations over all the globe, it has been fully established in modern times, yet was not wholly overlooked in remote antiquity.

Notions of the displacement of the ocean from lands of great extent which it once covered, occur in Ovid and Strabo; the perception of its importance became general on the revival of learning in Europe, and gave rise to many hypotheses in Italy, France, England, and Germany. It is the great truth which supports the Wernerian and Huttonian theories, as well as the otherwise baseless fabrics of fancy proposed by Burnet, and Woodward, and others of our countrymen.

Besides the proof thus offered that our continents were formed under the ocean, and only recovered from it after the deposition of many strata, enclosing the remains of many races of beings, we find more limited indications of the existence of fresh water and dry land contemporaneously with the production of some of the marine strata. How is this known? By the alternation of strata containing freshwater shells and other products, or land plants,

with those containing marine exuviæ. Thus it is certain that while the whole or greater part of the terrestrial surface we now behold lay unborn on the bed of the primeval deep, some land did exist, some lakes or rivers held fresh water, and the air nourished vegetables and animals as well as the sea.

But the greater proportion of organic remains found in the earth is clearly of marine origin. They are incredibly numerous, often perfectly preserved, and can be directly compared with existing species of mollusca, crustacea, zoophyta, &c. so as perfectly to determine their affinity and diversity. The progress of philosophical zoology and botany is here of the highest importance: these sciences enable us in many instances to state the degree of the analogy or difference observed, and to draw some important inferences not otherwise attainable. The comparison of recent and fossil species has now gone far enough to justify some remarkable deductions.

EXTINCT GENERA AND SPECIES.

Of many thousand species of marine zoophyta, mollusca, crustacea, fishes, &c. very few can be exactly paralleled in the system of living nature, most of them are extinct, and only to be understood by the application of laws derived from the study of the most similar existing races.

The amount of resemblance between the fossil and the recent tribes is extremely variable; a few are perfectly identical; a considerable proportion so far similar as to be referred to the same genera; a still greater proportion can be included in the same great families; almost all can be referred to the same great classes of the animal and vegetable kingdoms. The differences of form and structure are

thus known to be of the same order as those which at the present day belong to the productions of different climates and different local conditions. Thus, while some very large groups of fossils have only a very faint resemblance to existing forms of life, strike us with surprise and awaken a curiosity which can only be partially gratified,—the general effect of the whole investigation is to prove a unity of design pervading the fossil and living creations,—one general system is discerned,—and the variations are referred to *differences of circumstances.* To reduce these differences of condition to some general law, let us next attend to the distribution of organic remains in the earth.

DISTRIBUTION OF ORGANIC REMAINS IN THE EARTH.

The stratified masses of the earth containing organic remains are of different antiquity, as indicated by their relative position, of different chemical and mineralogical nature, and the situations in which they occur upon the globe are various; these three circumstances influence the distribution of organic remains. In the existing economy of nature we know that marine life varies with geographical situation, and changes with the nature of the oceanic bed. But the present races of beings which become engaged among the sediments of the ocean characterize only one period: the organic remains belong to many different successive ages of the world. Thus we must examine their distribution in the earth with reference to three points,—

1. The different periods when they lived.
2. The geographical situation of the locality.
3. The different rocks which enclose them—(other things being similar).

The bare proposal of such problems for discussion is enough to prove what real progress has been made in investigating the structure of the earth; and it is scarcely beyond truth to say, that as much is already known of the laws which govern the distribution of organic remains in the earth as of those which define the limits of life in the sea. Nevertheless, we must not imagine this subject so fully examined as to confer more than a provisional character upon the conclusions which follow; for *accurate results* on the subject are yet collected from a very small part of the surface of the globe.

1. The relative antiquity of the stratified rocks is found to be, throughout most parts of the world, the circumstance of principal influence in limiting the occurrence of organic reliquiæ. In every restricted tract of country, as the north or south of England, the fossil zoophyta, shells, and crustacea are different in the different systems of formations, and sometimes even in all the successive stratified rocks. Thus in the north of England the silurian system, the carboniferous system, the red sandstone system, the oolitic system, and the cretaceous system, all contain organic remains, and mostly in great plenty. Two things are here observed, first, that ALL the FOSSIL shells, &c. are clearly and completely DISTINCT from any known recent species; secondly, that with hardly one exception, all those of one system are distinct from all those of another.

2. In each system of strata lie entombed the exuviæ of entirely different races of beings, all successively buried in marine sediments on the same geographical area; a series of monuments which mark the numerous changes of organic and inorganic nature. Each stratum is thus proved to have been in its turn the bed of the sea. After the depo-

sition of a certain number constituting a formation or system of strata, all the phenomena were changed, sediments of a different nature were deposited, enclosing the remains of different races of living beings. The same things are true of equal districts in the south of England, in France, Germany, and America. It is therefore adopted as an axiom sufficiently demonstrated to be of general application, that in a limited district particular species of organic remains are distributed in certain assemblages of strata according to their relative antiquity. Certain races of organic remains are of higher antiquity than others.

To the discovery of these sure truths Mr W. Smith has a just and recognised claim. His labours date from 1790; yet we must not omit to observe that not only Werner, but Whitehurst, Mitchell, and Lister, and others, had some knowledge of a similar kind, more, perhaps, than can be inferred from the short notices left in their works, or in the memory of their pupils.

3. But these are local truths. The attention of modern geologists, resolved to follow out the masterly researches of Mr Smith, are directed to ascertain their generality. The law just expressed may be universally true, and prove every where changes of organic life proportioned to the time elapsed, and yet not permit us to infer that these changes were contemporaneously similar over all or even a great part of the globe, *unless* the organic contents are every where similar in the same or contemporaneous formations or systems of strata. The facts yet collected on this subject are too few to allow of very precise inferences; yet it is too important to be lightly passed over. It is found that particular species of fossils have rarely, even in the same stratum, an universal diffusion. Not even over the conti-

nent of Europe can many particular species be traced at all the points of a particular rock. One *certain* belemnite (*B. mucronatus*) is almost never absent from the European chalk, and is found in no other rock; a particular trilobite (*Calymene Blumenbachii*), and a certain coral (*Catenipora Lam.*) has been found not only in most localities of the silurian limestones in Europe, but also in America; but these are rare cases. Particular genera and families are more widely distributed along the strata to which they belong; for example, belemnites and gryphææ occur every where in the cretaceous and oolitic systems, and rarely or not at all in any other systems. Orthoceratites and goniatites occur every where in the silurian and carboniferous systems, and in none which lie above. Finally, each system of strata, as far as is yet known, appears, wherever it occurs, to exhibit in its organic contents identity, affinity, or analogy with those found with it at other points nearly in the ratio of the proximity of the situations. Hence, as a general rule, it is found that the marine organic contents of each system of strata are the remains of successively created and destroyed races of animals, each of which lived through particular periods of time, and no longer; that the families and genera living at one epoch were very widely diffused, but that each species existed only in a definite and mostly very narrow geographical area.

4. Nature of the rocks.—In the modern ocean we know that the distribution of many mollusca and crustacea is influenced by the nature of the bed or shore of the sea. Oysters love a muddy bank, cockles delight in sandy shores, lobsters seek subaqueous rocks. The same dependence appears amongst organic remains; for it is too remarkable to escape ordinary attention, that the ostrea deltoidea is col-

lected in immense oyster beds in the Kimmeridge clay; that an analogous genus, the gryphæa, lies in excessive abundance in the Oxford clay, and the argillaceous lias shales and limestones.

But zoophytes, as lamelliferous corals, echinida, and crinoidea, generally, are almost unknown in argillaceous rocks, unless when they are associated with calcareous portions, while they abound in many, if not all, the fossiliferous limestones.

This kind of dependence of certain races of fossil shells, &c. on the nature of the enveloping rocks, can be well studied in the oolitic and carboniferous limestone formations, where, limestone, sandstone, and shales continually alternate. There is a general accordance between the different oolitic limestones in the number and general character, and often peculiar species of fossils which they contain. In respect of the fossils, the limestones differ more from the sandstones and argillaceous strata than from each other. The same things are true in the mountain limestone series, with this addition, that the fossils are principally confined to the calcareous portions of the strata.

It would appear, therefore, that the conditions of existence of certain species of fossils occurred periodically, and coincided with the deposition of particular strata, as if the dictum of Cuvier were true,—as if the oceanic fluid had changed its nature, and its depositions and inhabitants changed in proportion. But before we adopt this conclusion, we must assure ourselves of the truth of what has indeed been long taken for granted by geologists, that the marine animals lived on or near the spot where their remains lie imbedded. This does not require long discussion. The general perfection of the delicate ornaments on

the surfaces of shells, echini, &c., the complete state of conservation of fishes, crustacea, &c., proves them to have undergone little or no violence, such as transporting from a distance in oceanic currents would necessarily occasion. In some cases the fossil shells, &c. have experienced the usual agitation of the shores of the sea, as in the forest marble group near Bath, the top of the oolite at Stamford, &c.; and this is of great importance in reasoning; but generally we may conclude that the doctrine is sufficiently exact which fixes the local residences of the animals near the place of sepulture of their shelly or osseous remains.

COMPARISON OF THE STRATIFIED AND UNSTRATIFIED ROCKS.

The arguments on which we rely for the proof of the subaqueous origin of all the stratified rocks may be thus summed up.

The stratified structure is that which is always assumed by successive depositions of sediments in water.

The materials (clay, sand, limestone, &c.) composing the strata of the crust of the globe, are exactly similar and in the same condition, or else very analogous, to deposits now forming under water in various parts of the globe, and similarly associated.

The organic contents of the rocks are such as admit of no other explanation, for they are mostly of marine or fresh water origin, and the few terrestrial reliquiæ which occur in them shew, by various circumstances, that they were drifted from the land or overwhelmed by the sea. By combining all these considerations, we arrive at the positive conclusion *that all the really stratified rocks* are of aqueous origin.

But when we turn to the unstratified rocks the same

conclusion does not apply. Independent of the universal want of this unequivocal mark of watery action (except under particular cases not really exceptional, as will appear hereafter), the following circumstances are decisive.

The materials of which the rocks are composed are neither similar to those now deposited by water nor in a similar condition. They are not composed of sands, clays, or limestone, but of a variety of crystallized minerals, many of them the same or very similar to those produced by volcanic agency, or the artificial heat of a furnace.

The association of these minerals into rocks is the same or very similar to the grouping of similar minerals in volcanic rocks. In several instances the products of volcanos and ancient unstratified rocks are identical. The variations of the different groups of rocks follow similar laws, and they occur under similar relations to the stratified rocks.

In these unstratified rocks organic remains do not occur (sometimes, indeed, portions of strata containing such remains are enveloped in unstratified rocks); and from the whole evidence no doubt remains of the igneous origin of the crystallized and other unstratified rocks.

It is very conceivable that, in particular circumstances, the effect of watery and igneous agency may be evident in the same rock. These agencies may have been contemporaneously or successively exerted; and thus combined, successive or confused results of two entirely different agencies may occasionally lead even the experienced geologist into error. But this does not affect the principle; inaccuracies of detail must often occur in descriptions and reasonings on natural phenomena, which involve various conditions and measures of force. Already, indeed, the clew is probably obtained for elucidating the *differences* as

well as the *agreements* of geological phenomena, and it is not necessary to say that no natural science can pretend to have made greater progress than this; for to know the causes of general agreement, and to discover the causes of partial diversity, is the whole problem of physical science.

Original Position of Strata.—The leading and fundamental fact of geology is the submarine origin of the stratified rocks; and the partial desiccation of the bed of the ancient sea is the general truth upon which all geological theory must be based; for in fact our examination of the structure of the existing land is nothing more than the examination of the successive deposits in the ancient ocean, varied by the effects of subterranean movements. One of the first questions which presents itself to the mind on considering this subject is this, Do we see these stratified rocks in their original state and place, or have any displacements and derangements happened to confuse their order and symmetry? The theoretical considerations connected with this question will come before us hereafter, but, for the sake of the descriptions of rocks which are to follow, it is necessary to settle the facts.

In this, fortunately, there is no great difficulty. By an investigation of the circumstances under which modern deposits happen in water, we find as a very general result, admitting of few, and those local exceptions, that these deposits ever tend to assume horizontal surfaces. Wherever the lateral influence of waves and currents agitates broad surfaces of water to a considerable portion of its depth, the earthy sediments (sand, clay, &c.), and chemical precipitates (carbonate of lime) are diffused by the movements with so much uniformity as to produce very regular strata, with a decided tendency to horizontal surfaces. Thus, all round the

British islands, the very moderate slope of the bed of the sea is extremely characteristic; between the Humber and the Elbe, a distance of 4° longitude, the greatest depth is about 200 feet. (Whewell on Tides, Phil. Trans.) And, as Mr de la Beche has shewn, if the British islands and the bed of the sea around them were raised only 600 feet above their actual level (as compared with the ocean), they would be joined to the continent of Europe, and surrounded on all hands by a vast area of flat, or rather gently inclined, land; for the fall from the coast to the new sea-line would be generally so gradual as to present to the eye one great plain, uniting the western coasts of Spain, Ireland, the Hebrides, and Scandinavia.

The same horizontality of stratified deposits is observed in the dried beds of ancient and modern lakes; it is seen in every delta and along all river sides, and even if, like the stormy Arve, the rivers sweep along large masses of stone through irregular valleys, and accumulate heaps of detritus, with much local irregularity, the general result is a plane surface.

There are indeed exceptions to this general truth. One of the most interesting is that brought forward by Mr Yates in his description of the sedimentary deposits in the lakes of Switzerland. Where a river discharges sediment into deep and tranquil water, the particles, when released from the lateral impulse, are in some degree in the same circumstances as materials thrown from a loaded waggon; the coarser matters accumulate into conical heaps round the point of entrance of the river, while the finer sorts pass through greater breadths of the water and form more extensive and less inclined deposits. (Jameson's Journal, 1830.) Another case of stratified deposits deviating con-

siderably from the horizontal, may happen when carbonate of lime is precipitated from solution, and suffered to fall in very tranquil water on a sloping or undulated bed. The thickness of the strata produced would be greatest in the deepest parts, and the whole deposit would grow thinner towards the edges.

Now, in fact, among the stratified rocks which compose the crust of the globe, examples of these exceptional cases do occur; instances are really known where coarse materials to a limited extent have been deposited in inclined positions, and carbonate of lime collected in particular forms and not generally diffused; but just as in the present economy of nature we find unequivocal evidence of the generality of the law of horizontal deposition of strata, so it certainly was in the older times. We are fully convinced, that for broad and extensive formations of strata composed of various successions of sands, clays and limestones variously stored with organic remains, there can be no risk of error in assuming, as a fact sufficiently proved, that they were deposited nearly level.

Position of Strata.—Assured of this fact, as a basis of reasoning, we may proceed to inquire into the actual position of strata, as they are seen in the desiccated parts of the old oceanic bed which now compose our solid land. The most general condition of the stratified rocks of all ages is to be not quite level, but inclined to the horizon in some one direction, and at some certain angle, in each locality.

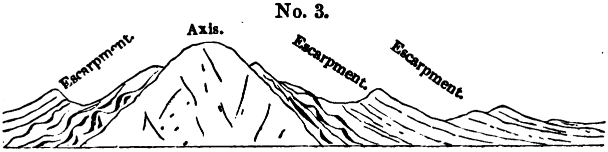
Over immense tracts of the earth's surface, the angle of inclination is extremely moderate; more than ¾ of the surface of Europe (and probably of the other continents) is occupied by strata which in common language may be said

to be nearly horizontal. This character of horizontality is indeed almost exactly merited by the strata around Paris, in the Great Plains of Northern Germany and Russia, the Basin of the Danube, Hungary, &c.; but as we proceed in any direction from such centres and lines of horizontal stratification, we find the rocks to assume more and more of some prevalent inclination, so as to permit the subjacent strata to come to the surface and present escarpments in particular directions.

These escarpments commonly look toward the nearest range of mountains; in that direction the inclination of the strata augments continually, and at length on the slopes, or in the midst of such mountain range, we find them very steeply inclined, absolutely vertical, partially retroflexed, or bent into strange contortions.

Among the Alps and Pyrenees, the strata which, in every part of their surface, were originally very little inclined, and which, at a distance from the mountains, retain nearly their original position, are thrown into various disturbed positions; the local effect of violent convulsions. By a careful study of the circumstances, we observe that these indications of disturbance augment continually toward the axis or centre of the mountain group; and that the direction of the movements has there been upwards. There has, in fact, been a real and violent *elevation* of the stratified crust of the globe, corresponding to the centre or axis of each mountain group.

No. 3.



This truth, sufficiently attested by observation in all parts of the globe, leads directly to another very important law of the phenomena of disturbed stratification. The centre or axis of the mountain group, and consequently of the disturbing movement, is generally *seen* to be a mass of *unstratified rock*, such as granite, sienite, &c., which shews, by a variety of circumstances, that it was not deposited in water, but rather crystallized from igneous fusion. Very often, indeed generally, proofs of its having been in a state of fusion at the time of the elevation of the strata, are found in the extension of veins of the crystallized into the sedimentary rocks, accompanied by characteristic effects of heat.

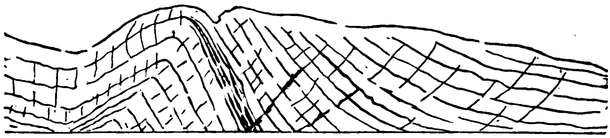
We are thus led to associate the phenomenon of the disturbance of strata, with the eruption of crystallized rock from beneath; and though the latter is indeed not exactly the *cause* of the former, but rather a concomitant effect of some general dynamical agency, geologists are not greatly to be censured who describe the phenomena as they appear, and speak of the disturbed positions of the strata, as *effects* of the elevation of unstratified rocks.

Once acquainted with this relation of the two classes of rocks, we are in possession of a clew to guide us through all the mazes of local geology; for it is equally true of small elevations of strata, as of all mountain chains, that the most general condition observable is the mutual dependence of these disturbances and irruptions of unstratified rocks.

Particular Positions of Strata.—One of the most common of the many forms in which the subterraneous movements alluded to have left the strata, is that of a longitudinal ridge, from which the strata decline on both sides, usually at very high angles; this is called an *anticlinal axis.*

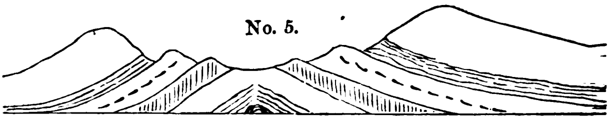
In some cases (Diagram, No. 4.) the strata are continuous

No. 4.



over the axis, as in the Ribblesdale system of faults in Yorkshire; in others (Diagram, No. 5.) they are removed along

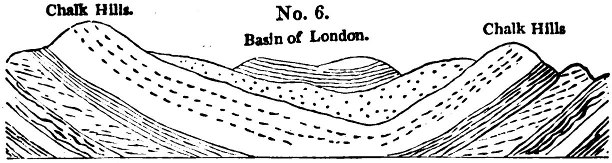
No. 5.



the axis so as to constitute what is called a valley of elevation. The southern Cordilleras are in this state.

The longitudinal depression or trough (Diagram, No. 6)

No. 6.



towards which strata decline, is called a *synclinal axis;* this is frequently placed parallel to an anticlinal axis.

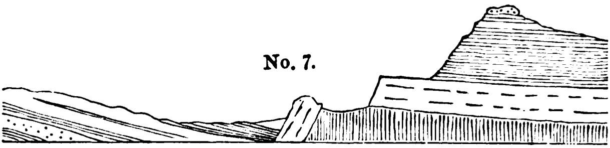
Cases of *conical elevation* do occur, but rarely; *elliptical ridges* are more frequent; and the centres and axes of such being removed more or less completely, make round or elliptical *valleys of elevation.* One of the most remarkable is that of Woolhope in Herefordshire. (Murchison.)

In some cases, instead of acclinal or declinal slopes to or from an axis, we have a complete *fracture* of the mass of strata along a vertical or inclined plane, parallel to which the

beds on one side are uplifted, and on the other depressed. This is called a *fault* or *slip;* almost every coal district and mining region in the world is full of such, though their number is, upon the whole, very much greatest in elevated districts, and least in the youngest strata.

The extent of displacement on one side of such fault is sometimes only a few inches; in other cases 10, 100, or 1000 feet or yards. The great Craven fault and Cross Fell fault in the north of England[1] is complicated with a narrow anticlinal axis, the extent of displacement produced by both is 1000, 2000, 3000, or even 4000 feet. (Diagram, No. 7.)

No. 7.



Irregular as seems the origin of these fractures (being occasioned certainly by pressure on planes of unequal resistance), yet some general laws of phenomena are known concerning them. The faults in any district range in many directions; yet they more specially follow two principal lines nearly at right angles to one another; they generally *cross* the anticlinal axis, and terminate in a remarkable master fault or axis of elevation.[2]

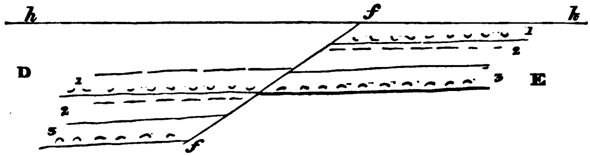
Another law has been long known to miners of the relation between the plane of the fault and displacement of the strata which it traverses; if the fault forms unequal angles

[1] See Phillips and Sedgwick in *Geol. Trans.;* also *Geol. of Yorkshire*, vol. ii.

[2] See *Geol. of Yorkshire*, vol. ii., and Hopkin's in *Cambridge Transactions.*

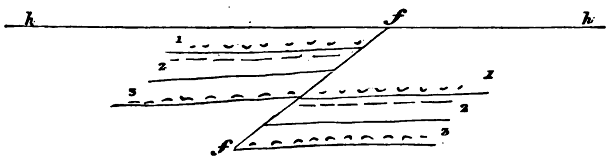
with the plane of stratification, the strata are almost always found depressed on that side towards which the plane of the fault dips or declines from the horizontal. In diagram (No. 8) *h h* being a level line, *f f* the plane of the fault

No. 8.



dipping from the horizon on the side D, the strata 1, 2, 3, &c. are found (relatively) *thrown down* on the side D, and (relatively) *elevated* on the side E. Not as in the next diagram (No. 9), which represents rare and exceptional cases with the same letters.

No. 9.

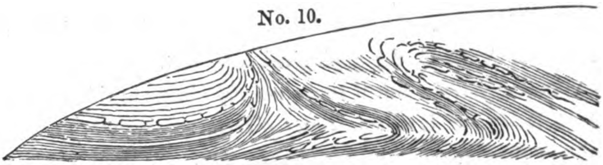


Both the anticlinal axis and the fault are, without impropriety, often called *axes of* (relative) *elevation.*

When the violence of the disturbing agencies has been extreme, the strata are not only thrown into high angles of inclination towards or from an axis, but sometimes actually rendered vertical (as in the Isle of Wight), or even retroflexed (as in the Malvern Hills). Even a more remarkable case is common among the Alps, as in the Lake of the Four Cantons, and in the Valley of Lauterbrun, where the limestones are bent into the utmost conceivable variety of

curvatures, evidently caused by great lateral and vertical pressure upon yielding materials. (Diagram, No. 10.)

No. 10.

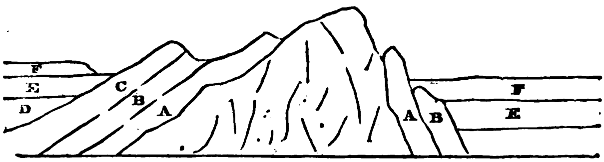


Areas of Deposition.—The study of the various circumstances under which disturbances of the strata are manifested, has assumed a very high degree of importance since the speculations of M. de Beaumont recalled attention to their connexion with general theory. It had been long known that the dislocations of the strata were of unequal antiquity. Even as early as 1791, Mr Smith found proof of the faults in the coal strata of Gloucestershire and Somersetshire, being anterior to the new red marl, for the horizontal beds of that formation lie level over the inclined and broken planes of the coal system. In the north of England, the coal-works from Nottingham to Aberford as well as those in Durham and Newcastle, indicate the same truth; but yet it is to M. de Beaumont that we owe the impulse which has given the investigation of the ages of disturbances a distinct station in geological science.

The data required for determining the geological age of a convulsion or disturbance of strata are simple, yet they cannot always be had with sufficient exactness. We must know what strata *are*, and what *are not*, displaced by the disturbance in question. If, for example, it be found that along any axis of elevation, the set of rocks included in the gneiss, mica-slate, clay-slate, and greywacke slate systems, are dislocated, but that none of the strata belonging to the carboniferous or other more recent systems have

participated in the movement, the conclusion is plain, that the disturbance happened *before* the deposition of the latter rocks, but *after* the production of the former. If the undisturbed strata D, E, F be consecutive with the disturbed rocks A, B, C, the geological data of the occurrence is *accurately fixed;* but if there be any chasm in this respect as A B—*—* E F, the *limits of error* are known, but the age of the fault is only *approximately fixed.* See Diagram No. 11.

Diagram, No. 11.



The principal difficulty, however, lies in the procurement of any really satisfactory data. If the disturbed strata be covered *along the axis* of movement by undisturbed deposits, the data must be correct, though incomplete, and the conclusion must be admitted; but this is a rare case; most frequently the observations are individually indecisive. Certain *older* strata are seen to be dislocated with reference to a certain axis; other newer beds *occurring in the vicinity* are not seen to be disturbed; if the observations can be repeated at many localities, not far removed from the axis, the negative may sometimes be sufficiently established. In such a case it generally happens that the disturbed strata are somewhere or other found unconformed in dip or in direction on the surface to those which are presumed to be undisturbed; on such evidence of unconformity, we might safely infer the geological dates of several great disturbances which have affected the Cumbrian slate district and other tracts in the north of England.

DESCRIPTIVE GEOLOGY.

LEADING DIVISIONS.

The history of the successive formation of the crust of the globe is so far like a narration of human events, that it admits of being placed in chronological order, and classed in periods more or less characteristic. Those periods are not at present reducible to the scale of historical time which is measured by the earth's rotation and revolution; yet the sequence of events is in many cases perfectly ascertainable, and something like a scale of relative time may be composed.

The basis of geological chronology is the succession of stratified rocks; the lowest are the oldest, and the uppermost are the most recent. Unstratified rocks present no such series; yet, by their connexion with the others, these also may frequently be referred to their true dates. On this account, the section of strata in any country is the foundation of all true and philosophical knowledge of its geological history.

Sufficient time has elapsed since the promulgation of the views of Werner and Smith on this subject to allow of a just estimate of their respective merits; both are amongst

the brightest names in geology. The principle of *geological time* was very firmly adopted by both of these eminent men ; both produced sections of strata to form the scale of geological time ; Smith analyzed the English strata with masterly accuracy,—Werner grouped the rocks of Germany into large and comprehensive systems : the one established the practice of local and exact research, the other encouraged a hope of arriving at general truths. Both of these are included in modern geology.

The series of strata in Germany was grouped by Werner, who in this was guided by earlier writers, under the heads of Primitive, Transition, and Floetz or Secondary rocks, terms which have been immeasurably censured, without sufficient reason.

The primitive, or most ancient of the known strata, were supposed to be of crystalline origin, and to contain no organic remains ; the secondary rocks to be mostly of sedimentary origin, and to abound in organic exuviæ ; the transition rocks were defined by intermediate characters. At a later period, Cuvier and Brongniart's researches round Paris, shewed the necessity of adding an upper term to this series of systems, viz. the Tertiary strata, which Werner had little opportunity of knowing.

The Wernerian hypothesis of the *origin* of the strata may, without hesitation, be rejected as entirely useless ; but his views of the leading groups of strata has had, and will long have, a decided and permanent influence in geology. The term Primitive rocks, as implying more than we know, is replaced by Primary ; and Du Halloy and others have united with these the cognate Transition rocks of Werner. Thus we have at present three well understood divisions,—primary, secondary, and tertiary strata,—between which are

many *transition strata*, linking the whole into one comprehensive succession, which contains all the monuments of mechanical, chemical, and vital phenomena open to the scrutiny of man.

In the following pages we shall attempt to exhibit the progress made in decyphering these monuments in the order of their inscription: this, indeed, is not the progress of *investigation*, which rather begins with the things best known, proceeds from the recognised facts and laws of diurnal geology, and gradually encounters the increasing difficulties which beset the inquiry into the ancient revolutions of nature; but our object is to state results in the smallest compass and most convenient order; and this is only to be attained by following the stream of time.

PRIMARY STRATA.

Primitive and great part of the Transition rocks of *Werner*. Inferior order of strata, *Conybeare*. Agalysian rocks, *Brongniart*.

Base of the Primary Strata.—*Inferiorly* the primary strata rest on unstratified, generally granitic rocks, so situated as to cut off all possibility of observation at greater depths. This granite floor,—this universal crystalline basis to the stratified rocks,—appears in many instances (Glen Tilt in the Highlands, Skiddaw in Cumberland, Land's End in Cornwall, &c.) to have undergone fusion since the deposition of strata upon it, for veins pass from it into the fissures of these rocks; this may even be considered one of the most general truths yet ascertained in geology. Some theorists have proposed the hypothesis, that granite is only

a fused mass of stratified rocks. To this we shall again advert, and at present shall only observe, that, whether that notion be true or false, it is enough for our present purpose that it recognises the general truth of the stratified rocks which are the products of water, resting universally on unstratified crystalline rocks, which, through whatever previous conditions their particles may have passed, have assumed their present characters from the agency of heat.

Igneous rocks, then, rest below all the aqueous deposits.

Nature of the Primary Strata.—The rocks included in this division may be referred to three principal types: Siliceous, Argillaceous, and Calcareous rocks. The most important siliceous rocks are gneiss, composed of the minerals called quartz, felspar, and mica (with or without hornblende, garnets, &c.); mica-slate, consisting of quartz and mica (with or without felspar, garnets, hornblende, &c.); quartz-rock, composed chiefly of grains of quartz agglutinated in various degrees (with or without mica, &c.); chlorite-slate, which, when highly quartzose, may be referred to this division, but, when passing to clay-slate, more naturally ranks with the next. Hornblende-slate has the same double relation. Sandstones occur in the upper parts.

The argillaceous rocks are less varied: Clay-slate, a fine grained, apparently simple, mass; grauwacke-slate, of a nature intermediate between this and common sandstone; grauwacke, a conglomerate of quartzose and other fragments in a basis of clay-slate; various shales.

The calcareous portions are somewhat remarkable among limestones, for their generally crystalline character; even the fossiliferous rocks have much of this feature, and all the older beds are really crystallized. (Garnet, mica, talc,

hornblende, augite, quartz, &c., sometimes occur in those portions.)

Induration or consolidation to a high degree, is a general property of these strata. There is, in fact, no sand, no clay, no marl, in the whole series.

Succession of the Primary Strata. The different rocks named are naturally associated in particular groups, according to geological time, and consequently admit of being usefully combined in artificial arrangements which proceed on the same basis. Thus, amid many local variations, it is certainly true that rocks of the general type of gneiss and mica-slate lie most frequently and abundantly at the base of the whole series, and contain no organic remains; that the coarser argillaceous, sandy, and calcareous rocks, become more abundant in the upper parts of the series, and yield stores of organic exuviæ, both of plants and animals. Between these extremes are found the deposits of clay-slate, chlorite-slate, &c. In consequence we have the following series of systems, or great assemblages of strata, in the primary division (*numbered* according to their *geological date*, but *placed* so as to represent their relative *superposition*).

3. Silurian system, sandstones, limestones, shales, &c. with many fossils.

2. Clay-slate, and greywacke-slate system, with some limestones and a few fossils.

1. Mica-slate, and gneiss system, with crystalline limestones, and few or no fossils.

GNEISS AND MICA-SLATE SYSTEM.

Geographical Extent.—Hardly any of the lofty mountain ranges on the face of the globe are entirely devoid of rocks

of this system, uplifted upon an axis of unstratified granitic masses, so as to be inclined at high angles to the horizon. The great European basin is defined by irregular elevations of this kind from the Frozen Sea to the Atlantic; by the Uralian and Caucasian chains, the ranges of Asia Minor, Greece, South Italy, and the Atlas; the irregular western border of Spain, Ireland, the north of Scotland, and Scandinavia, is of similar structure. Within this area, the Sierras of Spain, the Pyrenees, the Alps, and many minor mountains, shew the extremely wide expansion of this oldest known system of stratified rocks.

In the British Isles it is little known in England and Wales (about Snowdon and Skiddaw); but, in the Isle of Man, in all the very mountainous parts of Ireland (Derry, Donegal, Galway, the south-western and south-eastern districts), in the Western Isles, Zetland, and all the Highlands of Scotland, it is the predominant class of rocks.

Succession and Thickness of the Strata.—In the Highlands of Scotland the expansion of the gneiss and mica-slate system is extremely great, and the following general formula may be stated of the succession of the component rocks, it being always remembered that local variations occur, which cannot always be reduced to a regular scale in a country where no organic remains can be employed to verify the inferences from mineral character. The thickness of these rocks is very great, even to miles, but cannot be accurately stated.

Upper series. Chlorite-slates, apparently uniting the clay-slate and mica-slate deposits. No organic remains. It ranges on the whole south-east border of the Grampians, from near Aberdeen to Argyleshire.

Middle series. Mica-slates, primary limestone, quartz-rock, in various combinations, the former by far the most predominant, the others only locally important; the limestone occurs in different parts of the series. That of Loch Earn, Inverary, and Balahulish, is in the upper part, approaching to chlorite-slate; that of Glen Tilt, and the vale of Loch Tay, is in the lower part. No organic remains. This occupies a great part of the eastern and southern Highlands, north-west of Ireland.

Lower series. Gneiss, with primary limestone, quartz rock, hornblende-slate, &c. Gneiss is the predominant rock, and varies much in all respects; the others are of local occurrence. Mica-slate alternates with Gneiss. No organic remains. The gneiss series occupies nearly all the Hebrides, and very large tracts of the northern and north-western Highlands.

Primary Stratification.—The stratification of primary rocks is sometimes very evident and indubitable, as in the gneiss beds about Loch Sunart in Argyleshire, the limestones of Loch Earn and Balahulish, the mica-slate of Glen Croe, the chlorite-slate of Loch Lomond: but, in many cases, it is extremely difficult to pronounce a candid and just opinion whether a particular mass of such rocks is stratified or not. This arises from the causes which are found to produce partial embarrassment even among rocks of the secondary age. These are original *peculiarities of stratification*, and subsequent *change of structure* by molecular aggregation (under the influence of heat or other general agency).

The laminar and bedded structure of gneiss, mica-slate,

chlorite-slate, and primary limestone, is always more or less proportioned to the admixture of ingredients, just as in common sandstones, which are changed to flagstone by abundance of mica, but aggregated into masses of great thickness where this is absent. Besides this cause of variation, common to all siliceous and argillaceous rocks, there is a singularity in the lamination of gneiss, and the schistose rocks analogous to it, which seems to indicate that some peculiar agency different from the ordinary diffusive influence of water was concerned in producing it. Contortions in the laminæ of these rocks are so prevalent, as even almost to be exclusively characteristic of them. It is easy to see how such peculiar arrangements of the surface of lamination, and the occasional entire extinction of those surfaces, may, in fact, render it extremely doubtful whether the rock is in any respect stratified, because, in many instances, where *the beds or strata are very thick*, no other clew is to be found than that afforded by the *laminæ*, which generally *are*, but yet (as in common sandstone) often *are not* parallel to the planes of stratification.

There are, however, yet other causes which tend to confuse the evidence of stratification. In the neighbourhood of igneous rocks (granite, porphyry, &c.) the gneiss, and other similar rocks, seem to have undergone some alterations. MacCulloch assures us, that the contortion of the laminæ of the rocks augments near the granite veins, quartz veins, &c., and our own observations in Argyleshire lead to a partial adoption of this view. Another thing of importance has been noticed by Mr Weaver (Geol. Trans.) concerning *alternation* of really granitic beds with ordinary gneiss in Ireland. Whether these be *altered gneiss*, or interposed granite, is not material to the present discussion, if there

be, from whatever cause, such alternations of really crystallized and sedimentary rocks, the result must be a blending of the characters of the two classes of rocks, and the stratified structure may wholly vanish in particular tracts, through the local influence of heat.

Another very general cause of difficulty in determining the stratification of primary rocks arises from the changes of structure introduced among them since their deposition. The contraction of these, as well as of other rocks, has occasioned the production of a multitude of divisional planes or joints variously related to the surfaces of stratification, and often, especially in the finer grained and laminated rocks, assuming an admirable symmetry of direction and inclination. Thus tabular and other regular structures appear in the stratified primary rocks, which arrest the attention, and add a new cause of embarrassment.

What, then, is the fruit of all this discussion? It is the conviction that the gneiss, mica-slate, primary limestone, quartz-rock, &c. are stratified rocks; the most important evidence being the alternation of these different rocks, and the lamination of different substances in them, but that the causes which tend among all rocks to complicate the stratification with new structures, have gone to the maximum in these the oldest of all; the principal of these causes being heat, either locally exhibited in the neighbourhood of igneous crystallized rocks, or generally pervading the whole mass of deposits.

Composition of Gneiss, Mica-Slate, Quartz-Rock, &c.—The views just advanced of the changes of structure superinduced on these rocks, lead us to an explanation of what seems at first an extremely perplexing circumstance in the history of primary strata,—their crystalline or pseudo-

crystalline texture. Primary limestone is both stratified and crystallized. Gneiss and mica-slate are stratified, and yet they often closely resemble granite, which, because it is crystallized and not stratified, is ranked among rocks of igneous origin.

The case of limestone is soon settled. It is known, that, in contact with igneous rocks, the chalk of Ireland and the limestone of Teesdale, are turned to crystallized carbonate of lime; and experiments in the laboratory have left no doubt of the propriety of referring this crystallization of the limestone to the mere agency of *heat and pressure.*

The primary limestone is therefore crystallized, because it has been subject to high temperature, pervading, of course, all the rocks with which it is associated. But it occurs with nearly all members of the mica-slate and gneiss systems. All those rocks then have suffered the influence of heat.

In like manner, experimental proof has been offered by the chemist, that quartz-rock is merely sandstone altered by heat, as had been inferred from phenomena at the contact of such rocks, with the basalt and greenstone in Salisbury Craigs, Teesdale, and Shropshire; and thus we find reason to believe that some of the characters by which gneiss and mica-slate approach to granite, are owing to their having experienced considerable influence of heat. It is not, however, necessary to attribute to this heat more than the cementation of the grains of mica, quartz, felspar, &c., just as happens in quartz-rock. Some minerals may, perhaps, have been really *generated* by the heat (as happens to garnet near trap-dykes); but, in general, examination of the ingredients of gneiss, mica-slate, &c., shews the minerals to be really worn and fragmented crystals not very

different from those in common sandstones, which have indeed regular internal structure, but not a regular external geometrical form. Six-sided tables of mica can seldom be seen in gneiss or mica-slate; the pyramids of quartz have lost their angles, and the prisms of felspar their edges. Sometimes, it is true, the degree of wearing which the particles have suffered is very slight, and many considerations render it probable that the circumstances under which they were accumulated, differed materially from those which produced the sediments of the secondary geological era. According to these views, then, gneiss, mica-slate, &c. &c., though really stratified rocks, present greater resemblance than others to the granite rocks, because they are composed of granitic detritus, which has been only partially water-worn, and aggregated under the influence of high temperature, which has given a peculiarity to the molecular constitution, generated new minerals, and introduced symmetrical structures, which complicate or predominate over the traces of laminar and stratified aggregation.

Absence of Organic Remains.—The opinion, early introduced into geology, that the lowest stratified rocks are deficient in organic remains still holds its ground, and still appears to support the rather questionable separation of the gneiss and mica-slate system from the superior slate deposits, under the name of primitive rocks.

MacCulloch, indeed, states that organic remains (*Orthocerata*) occur in limestone lying in the gneiss tract of Loch Eribol, in Sutherland; and in the German translation of De la Beche's Manual (by Von Dechen), we find examples quoted from Hoffman of fossils occurring among gneiss and mica-slate in the Erzgebirge and Fichtelgebirge.

The fossils lie, indeed, in greywacke; but this is stated

to be really and clearly inclosed between beds of gneiss, mica-slate, &c.

A particular view on this subject has been gradually introduced into geological hypothesis, viz. that the mineral and structural character of gneiss, mica-slate, &c. is producible by long continued action of heat upon siliceous and argillaceous strata of any age. Thus in the Col de Balme the lias is supposed to have been metamorphosed into chloritic and micaceous rocks, analogous to those of the mica-slate. Those who adopt such views find it easy to escape from the difficulty presented by MacCulloch's and Hoffman's observations; but without entering on the subject at present, it is right to mention that the researches of Sedgwick and Murchison on the spot indicated by MacCulloch failed to confirm his testimony, and that in the mountainous border of the basin of Bohemia, as in every such range, *apparent enclosures of fossiliferous greywacke, between* gneiss and mica-slate, is hardly a case of sufficient importance to negative the universal result of direct researches, which all go to establish as a fact the total absence of organic remains from the whole of the gneiss and mica-slate systems. Is this absence of all traces of organic life to be admitted as proof that the globe was at that period unfurnished with the beautiful and wonderful variety of plants and animals adapted to the land, the air, and the sea, or may we suppose such did exist, but that their reliquiæ were never entombed in the rocks, or if there deposited, have been destroyed by subsequent alterations of their molecular constitution?

Igneous Rocks—Veins.—Besides the irregular granitic floor upon which all the gneiss and mica-slate system rests, and from which at many points veins or interspersed beds

pass up into these strata, many other masses of pyrogenous rock have been forced among the gneiss and mica-slate, so as to constitute dykes or irregular masses of large extent. Thus porphyry, greenstone, basalt, and other crystallized rocks are found mixed with the gneiss and mica-slate in various parts of the Highlands, Hebrides, and Zetlands. Of these the most frequent is porphyry, which indeed forms a very large region in the vicinity of Ben Nevis and Glen Coe, and is also abundant in Ben Cruachan, both in great masses and in dykes variously associated with granitic veins. It is perhaps not proper to describe the serpentine of Portsoy as forming dykes, for its vertical masses appear conformable to those of the mica-slate, quartz-rock, limestone, &c. so as rather to correspond with the notion of an interposed bed.

Metalliferous veins occur, but not plentifully, in the gneiss of the Highlands. At Strontian the lead veins have been long celebrated; they range east and west and north and south: copper also occurs in the vicinity. Such veins appear still less common in the mica-slate.

CLAY-SLATE AND GREYWACKE-SLATE SYSTEM.

Geographical Extent.—Few mountainous districts are wholly devoid of argillaceous primary rocks; but these deposits are not at all to be compared in extent with the older mica-slate and gneiss formations. If we look to the continent and islands of Europe we shall find a singular reciprocity in the distribution of these members of the family of primary rocks. The gneiss and mica-slates of the Alps, Pyrenees, and mountain borders of Bohemia, are not indeed entirely unaccompanied by such argillaceous deposits, any more than the Scandinavian and Highland chains,

and the north-western primary tract of Ireland; but the principal masses of the clay-slate system lie apart in the Harz and the Ardennes, in Brittany and Cornwall, the Welsh and the Cumbrian mountains, and the ranges of the Lammermuir and Donegal; yet under all these slate tracts lies the fundamental granite, and similar veins pass from it into the argillaceous covering. In some parts, as in Cumberland (Skiddaw), and in the Isle of Anglesea, slight traces of the older stratified rocks appear below the clay-slate, but the general fact appears to be that the deposition of the two systems was influenced by different physical conditions related to different geographical centres.

Succession and Thickness.—The districts of Britain in which the clay-slate system unfolds into the greatest variety of formations are the Cumbrian region and North Wales. The recent researches of Sedgwick and Murchison in Wales permit us to unite the sections of the principality with those of Cumberland, and thus to offer a nearly complete series of the members of this great mass of deposits. As before we *place* the groups in the order of *superposition.*

Upper Group, or Cambrian Rocks (Sedgwick), consisting of

Plynlymmon Rocks.—Hard, fine, sandy, or coarse greywacke and grauwacke-slate (without organic remains?), which is locally productive of roofing slates, and generally traversed by an extraordinary abundance of symmetrical fissures. Wales, Cumberland, and Westmoreland, the Lammermuir Mountains, Donegal Ranges, borders of Dartmoor, North Devon, Charnwood Forest. Thickness in the Cumbrian tract 3000 feet at least.

Bala Limestone.—Dark, slaty, calcareous rock, various-

ly associated with the slate, and locally rich in organic remains, both in Wales and Westmoreland. Limestone of Ilfracombe and North Devon? of the Harz, Norway, Brittany, &c.? Thickness in Westmoreland 100 feet.

Snowdon Rocks.—In this division are rocks of various colours, green, blue, purple, &c., and fine or coarse grain. Good roofing-slate abounds, and the peculiar fissility called *cleavage*, on which it depends, is very general in all the mass of rocks, which are some thousand feet thick both in Wales and Cumberland. In both districts also the sedimentary rocks are much intermixed with porphyries and greenstones, both in seeming beds and dykes, and many parts of the slaty rocks themselves are really amygdaloidal, or else composed of fragments of porphyry and other igneous rocks. No organic remains have been found in the Cumbrian district, but they occur in Snowdon. Thickness in Cumberland 3000 feet at least.

Lower Group, or Cumbrian Rocks (*Sedgwick*).

Clay-Slate.—This is a singularly uniform mass of laminated argillaceous rock, of a dark colour and smooth texture, with vertical cleavage and symmetrical joints. It is devoid of organic remains.

Chiastolite-Slate differs hardly at all from the preceding, except by including crystals of chiastolite and hornblende.

Hornblende-Slate.—This is very different from the rock so named in Glen Tilt, for its basis is clay-slate with intermixed crystals of hornblende or actynolite.

These three divisions may be above 3000 feet thick in Cumberland.

Stratification.—This structure is very evident in some parts of the clay-slate system, but very indistinct in others.

Thus in Cumberland it would be a difficult thing to say what were the planes of stratification in the Skiddaw slates, but for the assistance of the chiastolite slates beneath, and the red argillaceous rocks of Derwentwater above. The planes of stratification thus judged of appear to rise to the north-west toward an axis passing from Caldbeck Fells south-west to Egremont. The same direction and dip of strata is to be inferred from the interposed limestone beds of Coniston Water Head (Bala limestone), and it is confirmed by minute examination of the alternation and gradation, of the different sorts of slate.

But, certainly, on a *general view* of the country, the stratified structure is far from evident; so that many persons, impressed by the remarkable structure called cleavage which traverses nearly in vertical planes the surfaces of stratification, and the symmetrical joints which divide the rock into prismatic masses almost of geometrical regularity, leave the district under the impression that it is not at all stratified.

The same remarks apply to the slaty tracts of Cornwall and Wales, in which, especially the latter, both cleavage planes and symmetrical joints predominate over the stratification. That these structures are of later date than the stratified structure, is evident when we compare primary and secondary districts, for in the latter symmetrical joints pass through imbedded organic remains, and through many alternating sedimentary strata.

They are in fact superposed structures, and from what is known of the introduction of similar structures into ordinary clays and shales by the side and in the vicinity of igneous rocks, independent of general considerations, such as the high degree of induration of these rocks, there is

little doubt that the agency of heat is the general cause of these phenomena of structure. Argillaceous slaty rocks deposited from water, like common clays and shales, still retain traces of their original stratification, but they have undergone *generally* those changes depending on pervading heat, which later secondary rocks of similar original nature have experienced *locally* near the granitic region of the Col de Balme, near the Whin-Sill of Teesdale, and the whin-dyke of Coley Hill.

The Chemical and Mineralogical composition of these rocks is very analogous to that of common clays and shales; but the frequent admixture of igneous rocks, both in interposed beds and dykes, and the local metamorphism of the slate rocks, so as to assume amygdaloidal (Cumberland) and porphyritic (North Wales, Cornwall) structures, renders their exact origin a very interesting and unsettled subject of speculation.

Organic Remains, as previously observed, are (except in Snowdon and at Tintagel in Cornwall) almost confined to the limestones which interlaminate the slates. These are yet very imperfectly known. In the Cumbrian limestone occur calamoporæ, lithodendra, cyathophylla, orbicula, and, we believe, a much greater variety in the limestone of Bala. Some organic remains also occur in the coeval limestones of Devonshire. The Norwegian limestones, probably coeval, are by far richer in zoophyta, crinoidea, and conchifera.

Igneous Rocks, Veins, &c.—Granites, sienites, porphyries, and greenstones, are plentifully associated with the slaty rocks of Cumberland and Westmoreland, about Helvellyn, High Pike, Borrowdale, Wastwater, Ennerdale, &c., the granitic rocks, generally in great masses, which have burst through the slates,—the porphyries and greenstones

often interposed in partially conformable layers or passing through the rocks in dykes. Similar facts occur in the Lammermuir, in the Snowdon ranges, and the slates of Cornwall and Brittany; and in many cases the porphyritic beds have been subjected to the same disturbances as the slates in which they are interpolated.

The mineral veins of the Cumberland district pass generally east and west (rarely north and south), and yield sulphuret, carbonate, phosphate, arseniate, &c. of lead; sulphuret, carbonate, arseniate, &c. of copper; ores of iron, zinc, manganese, &c.

Those of Cornwall and Brittany have generally east and west courses, and north and south cross courses, with intermediate or quarter point veins. Ores of copper, tin, lead, silver, cobalt, antimony, bismuth, &c. abound in the rich tract of Cornwall. Similar statements apply to Brittany. The Snowdon and Cardiganshire chains yield lead and copper ores, also in east and west veins principally. The Harz is also a very metalliferous range.

It appears to be true as a general rule, that it is the Snowdon series or lower division of the Cambrian group which in Wales and Cumberland is the most highly metalliferous. In Cornwall, the lower portions are the richest, but nowhere, we believe, is the uppermost series of Plynlymmon rocks remarkably rich in metallic veins; for example, the Lammermuir. the south-east of Westmoreland, Charnwood Forest, the middle of Wales, part of the upper slates of Cornwall and Devon.

SILURIAN SYSTEM.

Geographical Extent.—It is to the labours of Mr Murchison, in South Wales and the bordering counties, that we

are indebted for a clear knowledge of the relations of this great mass of rocks, which were but partially noticed, and never consistently arranged by preceding writers. It is still to the district which he has worked, and specially to the counties of Hereford, Radnor, Brecon, Carmarthen, and Pembroke, that we must look for the most complete development of it yet made known. It does occur in Westmoreland and the Craven district of Yorkshire, and probably also in the southern primary tract of Ireland, between Waterford and Bantry Bay. There appears good reason to believe that part of the slaty rocks and limestones of the Harz and Norway, as well as the Eifel limestones, belong to it. Judging from organic remains which we have seen, it appears not unlikely that large tracts in the northern parts of the United States and Canada belong to this system.

Succession of Deposits and Thickness.—Mr Murchison's views on this subject, after mature reflection, appear finally to have settled into the following intelligible classification, which, however, can only be considered as *locally* applicable until the more extensive investigation which these rocks deserve in other districts, shall determine the general characters of the deposits. The order is that *of superposition.*

Upper silurian system, consisting of—

The Ludlow rocks, 2000 feet in thickness, which are composed of three groups, viz.

h. Upper Ludlow rock, an assemblage of slightly micaceous, grey, thin bedded limestones and shaly beds, containing a very great abundance of fossil shells, chiefly belonging to brachiopoda; some trilobites occur in it.

g. Aymestry limestone, a subcrystalline grey and blue

argillaceous limestone, full of pentamerus Knightii, and other brachiopoda; some corals also occur.

f. Lower Ludlow rock, a series of sandy, liver, and dark-coloured shale and flag, with concretions of earthy limestone; the organic remains are various and numerous.

The Wenlock rocks, &c. 1800 feet thick, including—

e. Wenlock limestone, a highly concretionary grey and blue subcrystalline limestone, singularly rich in particular genera of corals and crinoidea, brachiopoda; certain gasteropoda and polythalamic cephalopoda, and trilobites, are very plentiful in the Welsh, Salopian, and Dudley limestone, the same species occurring also in the Eifel and partially in the Harz, Norway, Russia, Brittany, and North America.

d. Wenlock shale, a liver and dark grey-coloured rarely micaceous shale, with nodules of earthy limestone; trilobites, brachiopoda, orthocerata, &c. occur in it.

Lower silurian system, consisting of—

The Caradoc rocks, 2500 feet thick.

c. Thin bedded, impure, shelly limestone, and finely laminated, slightly micaceous, greenish sandstone; with pentameri and other brachiopoda.

b. Thick bedded, red, purple, green, and white freestone, conglomeritic quartzose grits, sandy and gritty limestones, brachiopoda, trilobites, &c.

The Llandeilo rocks, 1200 feet thick.

a. Dark coloured flags, mostly calcareous, with some sandstone and slate. Asaphus Buchii, and other trilobites.

In tracing from Shropshire and Radnorshire the courses of these various rocks to the west, it is found that the lime-

stones lose their thickness and importance, and the distinctions of the several groups become, from that and other causes, less easily followed. This variation of numerical division is common to all the systems of stratified rocks: it leads us to doubt the applicability of minute subdivisions, however well conceived and locally exact, except for small geographical areas. In searching for the continuity of such systems we may conveniently follow rather such leading divisions as upper and lower silurians, though it is very probable that these will be often undistinguishable, especially as the development of the limestones (which in this, as in all other stratified systems, offer the most decided characters) is unequal and irregular.

STRATIFICATION AND ORGANIC REMAINS.

At this stage in the series of deposited rocks, all doubts and difficulties as to the fact of their complete stratification vanish entirely. In the alternation of sandstones, shales, and limestones, many of them fossiliferous, the fossil shells and crustacea, &c. differing in the different groups, what do we recognise but the very same principle as that which was detected by Mr Smith's researches among the oolites of Bath? *It is this close analogy* between deposits so far distant in geological date as the superior primary and middle secondary rocks, which constitutes the great interest of Mr Murchison's researches. We, who have known, step by step, the whole progress of his researches, claim the results as being peculiarly illustrative of the modern school of geology, which in all its investigations strives to detect, by a close inquiry into certain classes of phenomena among rocks of different ages, the unchangeable influences of nature. But there

is another point of view in which the silurian system demands our especial attention.

It appears highly probable that the organic remains of this ancient system are sufficiently numerous to justify satisfactory inferences on points of the greatest importance in the philosophy of geology.

In the first place, we must observe that these reliquiæ, though perhaps specifically different from those in the older limestones and other fossiliferous rocks of the clay-slate system, are mostly congeneric, of analogous structure, and similarly distinct from existing forms of life. There is evidently such an agreement of mineral and organic characters between the silurian and clay-slate systems, that both must be admitted to have been deposited under circumstances depending on the same or very similar physical conditions. That system is so linked with the mica-slate and gneiss, that the whole mass of primary strata may be conceived to be the result of physical conditions, gradually or periodically variable, but not suddenly interrupted. It appears that, in the deposition of the subcrystalline gneiss and mica-slate rocks, mechanical agitation of the ocean was rare and slight; and that, on the contrary, in the highest group of the primary strata, the sandstones and conglomerates indicate frequent and considerable watery disturbance.

Nearly in the same ratio, the monuments of organic life appear and grow numerous, the limestone bands become more regular and continuous, the stratification less complicated by superimposed structures, and the *characters of secondary strata appear.*

It was therefore not unphilosophical in Werner to propose for these formations, and some of those already rank-

ed in the clay-slate system, the term *Transition rocks:* such in truth they are; yet the term will probably fall into disuse, because the enlarged views of modern geologists have led them to recognise in all the varied mass of stratified rocks, only one long, though locally interrupted, series, every term of which is really *transitive*, connecting the earlier and later formations. Of this abundant proof will be found by every inquiring geologist.

The organic remains of the silurian system are most abundant in the limestones (*e. g.* Wenlock and Aymestry limestones); in calcareo-argillaceous layers (*e. g.* Builth and Llandeilo flags); or in layers of shale and sandstone associated with such calcareous deposits. The same is true (in a general sense) in the secondary strata, and, as far as examples can be quoted, it is also true in the lowest primary strata. The remains of polypiferous zoophyta, occur almost exclusively in the limestones; this is true for all the primary strata. The corals of the Wenlock and Dudley limestone, and those of the contemporaneous limestone of the Eifel, are aggregated in such forms as to suggest, though perhaps not to establish, the notion of these rocks being in fact ancient coral reefs. Crinoidea are less plentiful in these limestones than in some of later date: the brachiopoda and other mollusca, and also the trilobites, occur in the calcareous, argillaceous, and arenaceous rocks. Remains of fishes have been observed, even abundantly, but no traces of reptiles.

The character of induration or consolidation is less remarkable in these strata, than in all the rest of the primary rocks. The sandstones are, however, seldom soft; the argillaceous beds are shaly or slaty, and the limestones still subcrystalline.

Igneous rocks are associated with different parts of the

silurian system, under circumstances of great interest, though the geological date of their irruption can seldom be determined exactly. Mr Murchison, in describing them, adopts the convenient plan of referring them to their several parallel anticlinal or disruptive axes, and characterizing the nature of the igneous rocks and their effects upon the neighbouring strata. North of the Severn, Lilleshall Hill, the Wrekin, Charlton Hill, &c. mark parallel axes ranging from N.E. to S.W. and piercing through beds chiefly of the Caradoc rocks, the sandstones of which are converted to quartz-rocks at the point of junction of the trap. The ridge of Caer Caradoc contains many varieties of felspar rock, granite, and greenstone, and actynolitic amygdaloid.

On the flank of this axis of violent elevation, sandstones are converted to quartz-rocks, and particular strata occur composed of the materials of igneous rocks, the origin of which the author ascribes to subsidence of volcanic matter in water, and calls *volcanic sandstone.*

The mining district of Shelve, is an isolated tract separated from the Linley and Longmynd Hills by the remarkable ridge of quartz-rock, called the Stiperstones. It is made up of parallel ridges of trap and alternating depressions in the lower silurian rocks. Some of these trappean rocks alternate conformably with the stratified deposits, and are supposed to be of contemporaneous origin, and partly of the nature of the volcanic sandstone previously noticed; others are of the ordinary character of irrupted trap. Veins of lead-ore occur in the greywacke, near the junction with the trap.

The Breiddin Hills are formed in ridges running from E.N.E. to W.S.W. The eastern, or chief ridge, contains compact felspar rocks, slates, porphyries, greenstone, &c.

they burst through upper silurian rocks. The other main ridge contains chiefly columnar greenstone.

The Old Radnor group contains abundance of hypersthene, and passes from this to a fine grained greenstone. Near Old Radnor church, the upper silurian rocks are dislocated, and bands of imperfect serpentine occur between the trap and the limestone, which near the contact is wholly unstratified, crystalline, and hard; the shale is also hardened to a slaty substance: coatings and nests of anthracite, with minute metallic veins, appear near the junction. Other groups of trap, near Builth, range from N.E. to S.W., and resemble in many respects the rocks of the Shelve district. Other occurrences are noticed in Brecknockshire aud Caermarthenshire, and from the whole investigation, we find in the rocks which have been irrupted into these silurian strata, in their effects on the surrounding strata, in the alternation of pseudo-volcanic sandstones, and in the mineral springs which accompany the ridges of trap, not only the usual analogies to the effects of heat, but special resemblances to that form of the igneous action which is exemplified in volcanos. The facts are generally of the same order as those noticed among the older slates of the Lammermuir, Cumbria, Snowdonia, but more exactly and definitely traceable.

The circumstance of the dependence of the metallic veins on the axis of igneous rocks, in the Shelve district, is an example on a small and distinct scale of what is seen in Cumberland, Snowdonia, and most of the great mountain chains of Europe (of all geological ages). For it is a general truth, that metallic veins abound in proportion to the proximity of the situation to axes of dislocation, and irruptions of pyrogenous rock—a view first positively advanced by M. Necker.

GENERAL VIEWS CONCERNING PRIMARY STRATA.

The primary formations have so much of parallelism to each other, so much conformity of position, as to indicate long periods undisturbed by great convulsions. It is true, that among the old slates of Cumberland, between the Skiddaw and Snowdon series, a red conglomerate rock occurs, and seems to prove local disturbance; but this solitary exception rather suggests the commencement of that volcanic agency which in the period of the deposition of the Borrowdale and Langdale slates was very frequently exerted. Among the silurian rocks, conglomerates also occur, and seem to imply that part of the older Snowdonian and other slaty rocks were previously raised up to be exposed to atmospheric action; but yet the conformity of the silurian and Plynlimmon rocks, seems to forbid the notion of any *great convulsions*, though it may not at all affect the question *of gradual elevation* of part of the older rocks.

However, it is certain, that in the later part of the primary period, or perhaps after its close, great and general disturbances happened, which in many parts altered the aspect of the globe, by raising up large tracts of land, and dividing the expanded ocean by a multitude of mountainous islands. Without entering into a wide field of inexact discussion, we may dwell on some facts of this nature which have come to light concerning the ancient hydrography of the British islands.

It is remarked of the Grampians, that their elevated ranges no where include any masses of secondary strata, though round their flanks these rocks spread very widely and on all sides; they rest on the gneiss of Sutherland, mica-slate of Argyleshire, chlorite slates of Perthshire, &c. and in general appear in such relations to the ancient rocks

as to indicate that these had stood up above the ocean in which the carboniferous system was afterwards formed.

In studying the Lammermuir ranges, which are composed of slaty rocks less ancient than any in the Highland chains, the same old red sandstone border is found as that which encircles the Grampians, and under the same relations. These mountains, then, were also raised, though not to their present elevations, before the commencement of the carboniferous era. Now, it is very remarkable, that the Grampians and Lammermuirs are nearly parallel, both ranging nearly north-east: both are prolonged (across the channel) into Ireland, the former reaching Donegal, and the north-western projection of Ireland, the latter entering by Donaghadee on the eastern coast of Ireland, and proceeding inland to Cavan. In Ireland these prolonged ranges also shew the same independence of the carboniferous deposits; and the same results apply to the south-east border of the island.

Again, the same north-east range accompanies the slaty rocks of the Isle of Man, and it is recognised in a very distinct manner in the insulated and romantic district of the English Lakes. The axis of these slaty tracts passes north-east and south-west; and the nearly circular mass of primary strata is begirt by a belt of later red sandstone, limestone, &c., all evidently unconformed to the axis of the slates. The date of one of the elevations of the Cumbrian slates is thus probably fixed before the commencement of the carboniferous era.

The slaty ranges of North Wales have the same direction, north-east and south-west; they are also, probably, or rather certainly, anterior in elevation to the commencement of the carboniferous epoch; and, finally, the axis of

the Cornish and South Devon slates has the same general direction, and these rocks, probably, were elevated before the deposition of the carboniferous system.

Most of these mountains have an axis of granite and other pyrogenous rocks. Thus, a great number of parallel mountain ranges were produced by disturbing movements within one geological period, the result being, in each case, one, or a number of anticlinal axes, in each physical region, parallel to each other. It is impossible not to be struck with the probability thus arising, that, in the direction of convulsive movements, some regular laws are discoverable. In fact, if we were to be satisfied with one instance, this north-east direction among so many presumed contemporaneous elevations would establish the truth of Elie du Beaumont's hypothesis, which would have us recognise, as a principle capable of practical application, that parallel mountain ranges belong to the same era, and the same exertion of disturbing forces. This must be, however, subjected to further and more rigorous trials before it can be adopted among the admitted generalizations of inductive geology.

Though it thus appears evident that many of the most marking characters of British physical geography have so old a date as disturbances anterior to the carboniferous system, yet, on the continent of Europe, this is by no means the case; for the Alps, Pyrenees, Carpathians, and Apennines, are of more recent date, and, at the time when the Grampians sent streams and detritus to straits where now the valleys of the Forth and Clyde meet, the greater part of Europe was a wide ocean.

The state of the globe during the period of the production of the primary strata may never be fully disclosed by geological inquiries, aided by higher departments of know-

ledge: yet, as a view of the successive conditions of the globe, however imperfect, constitutes the very essence of philosophical geology, it is necessary to ascertain what progress has been made in this dark research into some of the earliest natural records of creation. It is remarkable that the lowest of all the known systems of stratified deposits should be at once the most extensive, the most nearly universal, the most uniform in mineral character, the only one from which organic life appears to be totally excluded, and in which the character of mechanical aggregation is the most obscure. Most of the circumstances are original, though the latter has been apparently influenced by superposed structures, due to subsequent agencies. Can we hesitate to admit that the globe was then in a condition which has never since occurred to it? Does it not strike the mind as a reasonable hypothesis, that the ocean was, during the period when gneiss and mica-slate were formed, unfitted, by some peculiarity of condition, for the support of living beings? Such peculiarity, to judge from the deposited rocks, was not of a chemical nature, for these are not of a description to countenance such an opinion; on the contrary, the gradual introduction of fossil exuviæ in the superior strata, till at length, as we ascend in the scale of rocks, they are unfolded in great abundance, seems to point to some slow change of a pervading physical condition.

In accordance with the undoubted truth of the general expansion of rocks of igneous origin below all the stratified masses, we naturally inquire if the agency of subterranean heat is of a kind to account for the phenomena observed. It is obvious that, when and wherever the supposed high subterranean temperature was applied most directly to the base of the ocean, so high a temperature would be

maintained therein, as to be incompatible with the existence of organic beings; changes would be produced upon the igneous rocks in an expanded thermal (agitated) ocean, quite different from those occasioned by lateral movements in later times through narrower channels of cooler water.

It does not appear improbable that a hydrothermic action, of the nature suggested, may be found sufficient to account for the remarkable resemblance between the (primitive) granitic, and the (derivative) gneiss rocks,—their almost universal diffusion,—the singular undulated lamination, rather than stratification, which belongs to so many of the older primary rocks,—and the absence of organic life; while, as the form of the globe was changed by subterranean disturbances, and mechanical agencies arose to importance, the sea received partial deposits from emerging lands into its contracted and variously ramified basins, and the communication of heat from below was sufficiently retarded by the intervention of solid rocks (gneiss, &c.) to al low, at least partially, temperatures suited to particular races of animals. It appears somewhat in favour of this view that the races of animals are, for the most part, very peculiar,—their association with abundance of corals seems to justify a belief that they were suited to a warm climate,—and the disappearance of nearly all these genera and families, after passing through a few more formations and systems of strata, is at least in harmony with the conditions assumed.

But this hypothesis, suggested by consideration of the phenomena, assumes quite another character, when compared with deductions from the admitted fact of the former igneous fluidity of the mass of the globe. From that important truth, as we deem it, it seems to follow necessarily that the globe should pass through many stages and changes

before, in any part of the surface, the conditions could be obtained, within which the Almighty Architect of the universe has seen fit to restrict the exhibition of organic life. One of the most direct and important of these, and the most obviously influential on mechanical, chemical, and vital phenomena, is the diminution of surface temperature: this having arrived, locally or generally, at a certain point, the unchangeable laws of nature relating to organic life, which are but the expression of the will of God, began to operate; and it is not one of the least curious of the adjustments of the terrestrial creation, that the diminution of the surface temperature is limited. A certain point once reached, the prescribed conditions of organic life once attained, they assume a character of stability,—a regularity of effects which enables a finite but intelligent being to trace them back toward their origin.

SECONDARY STRATA.

Base of the Strata.—In consequence of the disturbing movements already alluded to, which have broken up the primary rocks into various irregular masses, and in places thrown them off entirely from granitic nuclei and axes, the secondary strata have not always, nor indeed generally, their surfaces parallel to those of the primary age. On the contrary, the two classes of rocks are unconformed to each other; so that the same secondary strata may rest in some part of their range on gneiss, in other parts on clay-slate or silurian rocks, or, without any such intervention, on granite, according as these rocks, after the convulsive displacement of the crust of the globe, formed respectively the bed of the sea.

As a general but not universal fact, it is found that in the vicinity of elevated mountain masses the secondary strata are more nearly horizontal than the primary; hence they were included by Werner in his class of floetz or flat-lying rocks: but this classification, founded on a geological accident, is not satisfactory, though in fact it agrees nearly with the modern divisions.

Nature of the Secondary Strata.—They consist of three sorts of rocks, deriving their most prominent characters from three particular substances, viz. Siliceous, Argillaceous, and Calcareous rocks. On comparing them respectively with the corresponding forms of the primary series, little if any chemical difference can be established between the two classes. In the constituent minerals of the siliceous and argillaceous rocks also a great resemblance prevails. It is still quartz which constitutes the great bulk of the masses. Mica interlaminates many sandstones, and felspar varies the substances of others. Some clays are but a finer and more argillaceous kind of sandstone, just as some clay-slates are not obviously distinct from an argillaceous form of mica-slate. But yet, on a close comparison, we find the condition of these mineral ingredients somewhat different: the grains of quartz, mica, and felspar are in fact more worn on the surfaces, more broken and fragmentary in the secondary than in the primary strata. Also the aggregation of them is so far different, that the influence of sedimentary aggregation is extremely evident in all the secondary strata. The degree of consolidation of the mass is generally much less than in the primary groups; soft as well as hard sandstone, clay as well as shale, soft as well as hard limestones, occur continually. And just as in the primary strata the induration and subcrystalline aspect of

the rocks was at a maximum in the older systems, so in these the contrary characters, softness and earthiness of texture, become the most conspicuous in the upper or most recent groups.

Thus it is evident that the consolidation and molecular aggregations of the rock masses of similar chemical and mineral nature are dependent on general influences, such as pressure and heat, whose effect would naturally be greatest in the oldest rocks, because these have been not only exposed the *longest time* to their influences, but also submitted to the highest degrees of their action.

Succession of Secondary Strata.—Three characters are employed in establishing the classification of secondary strata; first, their mineral constitution; second, their respective conformity or unconformity; third, the nature of their organic contents; in many instances these coincide remarkably; where they differ the classification is embarrassed. All the classifications, however, are to be supposed only locally true; for it is already ascertained that none of even the larger assemblages of secondary strata are universal or even very general in their distribution, nor very uniform in any one of their characteristics, except for limited areas. The most convenient classification for the European basin is, however, found to be sufficiently applicable to all the Mediterranean and Transatlantic regions, part of Central Asia, and the basin of the Indus.

The British series of secondary strata is one of the most complete in Europe, and sufficiently developed, even in the parts where it yields to the German type (red sandstone system), to serve as a general basis of comparison. The following is a concise scheme of the arrangement usually adopted in Great Britain:—

Names of Formations.	Thickness.	Remarks.
	Feet.	
7. Cretaceous System,	1,000	Composed of soft white limestones and argillaceous and siliceous rocks, all conformable in stratification, and containing similar groups of organic remains,
6. Oolitic System,	3,000	A complex or polymeric series of calcareous, argillaceous, and arenaceous strata, associated in several rather similar groups of three terms each (limestone, sandstone, clay). The organic remains of the whole system somewhat similar, yet in fact differing in each group, and in each term of the groups.
5. New Red Sandstone, Saliferous or Poecilitic System,	1,200	Arenaceous, argillaceous, and calcareous strata, intimately associated in several repetitions. Red colour very predominant. Organic remains few and local.
4. Carboniferous System, . .	6,000 to 16,000	Calcareous, arenaceous, and argillaceous strata, with beds of coal and ironstone. The limestones usually low in the series, the coal most abundant above. Many land plants with the latter, the former with marine exuviæ considerably *analogous* to those of the silurian system.

CARBONIFEROUS SYSTEM.

Geographical Extent.—This valuable series of strata, to which Great Britain owes so much of her commercial prosperity, is extended irregularly over the basin of Europe, in North America, Australia, &c. It occupies large breadths in Scotland, Ireland, England and Wales, and lies in patches in various quarters of France, Germany, Poland, and Russia. Commonly it is found at the foot or on the

flanks of primary mountains which had been previously uplifted, so that its stratification is not in accordance with theirs. In particular regions, however, there is no such break in the continuity of deposition, but, as in Herefordshire, the passage is gradual from the upper silurian sandstones and shales and limestones to the limestone, shales, and sandstone, and coal of the carboniferous systems. In such a district it might be quite reasonable (since the organic remains, though minutely different, are often generically similar) to unite the upper primary and lower secondary rocks; but this local practicability must yield to general convenience.

Succession and Thickness of the Strata.—The variations in the development of the carboniferous system are considerable, and its occurrence is often in detached portions: it is therefore requisite for obtaining a general section, to combine the results of different and independent observers. The most complete view of the lower part of the system is found on the border of Wales adjoining the silurian rocks. The middle and upper portions are most fully exhibited in the north of England. There are three great formations included in the carboniferous system.

Upper Formation, or Coal Measures; three thousand feet thick in the north of England, consisting of abundance of sandstone and shales, layers of ironstone, and beds of coal. Of these are many alternations, constituting a series of many nearly similar terms, usually containing at least the three substances,—coal, sandstone, and shale. Scarcely any limestone occurs in this upper coal-measure series. One bed is, however, found in the Yorkshire coal-field, containing *marine shells,* while in all the rest of the strata nothing but fresh-water

and terrestrial exuviæ occur. A limestone bed with estuary shells is found in Shropshire, and near Manchester.

The coal seams, twenty or thirty in number, amount in all to a thickness of about sixty feet, in a mass of shales and sandstones at least 3000 feet. Nearly the same thickness of coal occurs in the coal-fields of Newcastle, South Wales, &c. though the earthy substances enclosing the vegetable products vary in nature and thickness. The thickest coal-seams in Staffordshire and Ayrshire, ten or fifteen yards, are in fact composed of many beds of different qualities aggregated together. The quality of coal is partly dependent on the plants of which it was originally composed, and partly on subsequent changes produced by subterranean movements, effects of heat, &c. The principal differences arise from the variable quantity of gaseous matter. In the stone coal (blind coal or culm) of South Wales, Kilkenny, and Virginia, which burns like coke, there is little or nothing but carbon and earthy admixtures. The box or cannel coal of Lancashire and Yorkshire, which blazes like a candle, contains nearly half of its weight of gaseous matter. There is but little coal, and that in the lower part of the series, in Ireland.

The ironstones of a coal district lie generally in layers of nodules, each frequently enclosing a leaf or shell, or some other nucleus of molecular attraction.

The shales are bituminous or sandy; the sandstones laminated or massive, micaceous, argillaceous, subcalcareous, or felspathic, very rarely of a red colour, though blue, yellow, brown, white, and other tints prevail. Chalybeate springs are general, and salt springs not uncommon in the northern coal tracts.

The Mountain Limestone Formation is best examined in the north of England[1] in the region between Pendle Hill and the Tyne. The whole series undergoes great changes, so as to afford northern and southern types applicable to all parts of the mountain limestone formation yet known in Europe.

The Southern Type, complete in Derbyshire and the south of Yorkshire, is composed of three terms, viz.—

Upper Term.—Millstone grit, a coarse sandstone, in one, two, or three masses, with shales and bad coal.

Middle Term.—(Limestone shale), a thick mass of bituminous shale, in which locally black limestone bands and nodules of ironstone occur.

Lower Term.—Limestone of Derbyshire (Lower Scar limestone of Sedgwick and Phillips), a great mass of calcareous rocks almost entirely free from arenaceous and argillaceous admixture.

To this type all the south of England mountain limestones, as well as those of Ireland, Belgium, Dusseldorf, and Silesia are to be referred.

In the *Northern Type* the same three terms are compounded and otherwise varied.

The upper group is composed of three millstone grit rocks, alternating with shales, laminated sandstones, coal seams, ironstones, chert beds, and thin limestones.

The middle group consists of shales alternating with sandstones mostly laminated, ironstones, coal seams, chert beds, and five or more limestone rocks, each from ten to eighty feet thick. (The name of Yoredale rocks is given to this group in Yorkshire.)

[1] See *Geology of Yorkshire*, vol. ii. and Sedgwick's *Memoirs in Geological Proceedings and Transactions.*

The lower group consists of limestone, alternating with shales and some sandstones, coals, &c.

To this type belong all the Northumberland limestones, and those of the basins of the Forth and Clyde. The limestone of Burdiehouse, near Edinburgh, is maintained by Dr Hibbert to be of fresh-water origin.

The lower part of the group, round the Cumbrian mountains, and along the Penine escarpments, from Brough to Brampton, contains alternating red sandstone beds, thus constituting a real transition to the next or old red sandstone formation.

The old red sandstone formation varies in its character so as to offer little that is really of general application except its colour, and the absence of coal, and rarity of limestone. Along the flanks of the Grampian, Lammermuir, and Cumbrian mountains, it is chiefly a rude conglomerate of pebbles torn by violent floods from the neighbouring high ground; but on the borders of the Welsh slates it is a complicated mass of arenaceous, calcareous, and argillaceous strata, graduating to the upper silurian system. Mr Murchison has thus classed the beds 10,000 feet in thickness, which he ascribes to the old red sandstone of the Welsh border:—

Upper part.—Red quartzose conglomerate, overlying thick bedded sandstone. (Without organic remains.)

Middle part.—Red and green (mottled) concretionary limestones, with spotted argillaceous marls and beds of sandstone. (Singular fishes, Cephalaspis of Agassiz.)

Lower part.—Flaggy, highly micaceous, red and green sandstone. (With shells.)

In the Geology of Yorkshire, vol. ii., is the following conspectus of the whole carboniferous group:—

	North of England and Scotland.	Derbyshire, North and South Wales.	Belgium and South of England.	Ireland.
Coal Formation	Coal, shale, grit, and ironstone	Coal, shale, grit, and ironstone .	Coal, shale, grit, and ironstone .	Coal, shale, grit, and ironstone.
Transition Series	*Millstone grit*, coal *shale* . .	*Millstone grit, or fare-well rock, shale*	*Millstone grit, or fare-well rock, shale* .	*Kulkeagh grit.* *Kulkeagh shale.*
Carboniferous Limestone Formation	Yoredale rocks. Limestone, Gritstone, Shale, and Coal	‘ Limestone shale’	. . .	Kulkeagh limestone. Loch Earn shales and grits.
Transition Series	Lower Scar limestone group .	Mountain limestone .	Limestone and shales	Enniskillen limestone.
Old Red Formation	*Alternations of red sandstone and lime-stone* . .	*Alternations of red sandstone and lime-stone* . .	*Alternations of red sandstone and lime-stone* . .	*Alternation of red sandstone and limestone.*
	Red sandstones and red conglomerates .	Red sandstone and con-glomerates .	Red conglomerates	Red sandstone and conglomerate.

STRATIFICATION.

This varied series of rocks shews, in all its parts, the clearest proof of successive deposition; laminæ, beds, strata, whole rocks, and groups of rocks, are here seen to be generally parallel. It is, however, very true, that in each kind of rock the phenomena indicative of successive deposition are so far different as to admit of definition. The argillaceous members are universally laminated, but it is rare to see the laminæ aggregated into beds. In a thickness of a few hundred feet, are many thousand laminæ, but *no real beds;* in a mass of limestone, forty to eighty feet, are *no laminæ*, but many beds; in micaceous sandstone, are both laminæ, and beds; and in some block sandstones are oblique laminæ and irregular oblique or waving beds. Does not this shew the imperfection of the nomenclature commonly used, which confounds all those various *structures of deposition* under one vague term of stratification? Yet, on the other hand, how full of instruction are those different phenomena: are we not clearly informed by them of the different conditions of the aggregation of the different chemical substances? Is it not apparent that the deposition of the argillaceous beds was subject to only minute and short interruptions; that the limestone rocks were formed at intervals; and the sandstones accumulated with much irregularity?

The deposition of limestone is of an oceanic character; its maximum thickness and purity is in one direction, while that of the arenaceous and argillaceous rocks lies in another, and marks the agitation of the sea along its ancient shores, where rivers and inundations brought sediments to be swept away by the tides and currents.

The organic remains of the carboniferous system are extremely numerous: upwards of four hundred species of

animal exuviæ have been figured from the mountain limestone alone; probably 200 species of plants belong to the coal measures, and it is certain that in both these formations considerable additions will yet be made: a few remain to be added from the old red sandstone. The following short summary of British species is all that our limits allow us to introduce:—

	Coal Measures.	Mountain Limestone.	Old Red Sandstone.
Plants—Marine . .	1	...	...
Terrestrial . .	150	...	...
Zoophyta—Polyparia .	...	41	...
Crinoidea .	...	40	...
Echinida .	...	3	...
Mollusca—Conchifera . } Plagimyona . }	10	36	...
Mesomyona .	4	24	..
Brachiopoda .	...	110	a few.
Gasteropoda .	1	95	...
Cephalopoda Monoth	...	10	...
Polythal	3	78	...
Crustacea—Trilobites, &c.	...	10	a few.
Fishes . .	10?	a few.	a few.

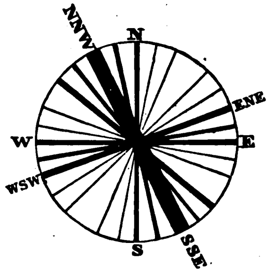
The account of plants is derived from comparison of the works of Brongniart, Lindley, and Hutton, &c. and from private sources; the other parts are chiefly taken from the Geology of Yorkshire and Sowerby's Mineral Conchology.

SYMMETRICAL STRUCTURES.

The jointed structure of rocks of the carboniferous system has been minutely investigated. In the Geology of Yorkshire, vol. ii. it is shown, from eighty-five observations in the carboniferous system, that in the mountain limestone and coal tracts of Yorkshire, the *long joints* affect certain principal directions, so that two positive axes in

which these divisional planes are most frequent, are traced at right angles to one another; and two negative axes in which *no* long joints have been observed, also at right angles to each other. The axes of frequent joints run N.N.W. and S.S.E., and E.N.E. and W.S.W.; the negative axes are N.E. by N., and N.W. by W. This singular result of observation harmonizes with the principal directions of mineral veins in the district bordering on the great Crossfell and Craven faults; it also bears a close analogy with the deductions from mechanical theory of Mr Hopkins, (Cambridge Trans. 1836), as to the production of planes of fissure at right angles to each other, in cases of continuous pressure being applied to large areas of the earth's lamellar crust.

No. 12.



The directions above named of the positive axes, obtain in newer strata (oolitic and red sandstone systems), and in situations at great distances from the Penine faults, and it appears probable that the joint planes are due to extremely general agency.

These researches should be followed up in other districts and in other systems of strata. The following table is extracted from the work above named, and it refers to diagram, No. 12.

Table of the Directions of Long Joints in Yorkshire.

Names of Formations.	No. of Obs. in Yorkshire.	W. by N.	W.N.W.	N.W. by W.	N.W.	N.W. by N.	N.N.W.	N. by W.	N.	N. by E.	N.N.E.	N.E. by W.	N.E.	N.E. by E.	E.N.E.	E. by W.	E.
Magnesian Limestone	4	...	...	...	1	...	1	...	1	...	...	...	...	...	...	...	...
Coal . .	3	...	...	...	...	...	1	1	1	...	...	...	...	...	...	...	...
Millstone Grit .	13	...	...	...	..	1	5	2	...	...	...	...	...	...	4	1	...
Chert Group .	57	...	...	...	1	4	6	...	...	...	...	...	1	...	4	1	...
Yoredale Series .	35	...	2	...	1	1	8	5½	5	...	...	...	2	1	3	2	4
Scar Limestone .	15	1	...	...	4	1	2	1	2	...	...	...	...	1	1	...	2
Old Red Sandstone	1	...	...	...	...	...	...	..	...	1	...	...	...	...	.	...	...
Whin Sill .	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1
	89	1	2	0	7	7	23	9½	9½	1	...	...	3	2	12	4	7

Igneous rocks are of frequent occurrence in the carboniferous system of the British islands, especially in the northern parts of England and southern parts of Scotland. It is very deserving of attention, that they are principally of the augitic and hornblendic family of igneous rocks. Greenstones and basalts are the prevalent rocks which lie in interposed beds, or fissures in the stratified limestones, shales, and limestones.

While among the slates of Cumberland and the Lammermuir prophyritic rocks of many kinds abound, the coal-measures and limestone rocks, not far removed, have only basaltic or greenstone masses mixed with them.

The porphyry of the Cheviot and some other points along the Tweed, may indeed be ranked as exceptions. In Northumberland, Cumberland, and the northern part of Yorkshire, a stratiform mass of greenstone and basalt (whin sill) is interposed in the midst of the limestone series, apparently originating in several submarine lava currents. In Derbyshire, a somewhat analogous rock ("toadstone") interlaminates the limestone; in the Clee Hill, a mass of basalt ("jewstone") has overflowed the coal. More commonly, through all the coal-field of Durham and Newcastle, and not unfrequently in the coal-basins of Scotland, rocks of the same kind have been injected in the fluid state into open fissures of the sandstones and shales, constituting whin-dykes. At the point of contact of these crystallized rocks with the coal, the latter is converted to coke (North of England), or to anthracite (Old Cumnock); earthy limestone is converted to crystalline (Teesdale); shale and sandstone are hardened to jasper (Salisbury Crags, &c.); garnets are generated in the shales of Teesdale. It is

worthy of remark, that the 'whin-dykes' of the North of England are often *unaccompanied by dislocation.*

Mineral veins abound in particular parts of the carboniferous rocks, chiefly in the limestone districts, and near to some considerable dislocations or axes of distinct elevation. Scarcely a single mine in the British islands is worked in the old red sandstone, or true coal-measures; very few are established in districts which, like a large part of the Irish limestone, are removed from axes and centres of disturbance. But the dislocated mountain limestone of Cumberland, Durham, Yorkshire, Derbyshire, Flintshire, Mendip, and South Wales, and partially that of Belgium and Silesia, is characterized by prevalence of veins of lead, copper, calamine, and oxide of iron. There is seldom found in these districts the same great variety of metallic ores as in the older primary tracts; the vein stuff (matrix of the ore) differs according to locality—fluor-spar abounds in the mines of Aldstone Moor, &c.—carbonate of barytes in Derbyshire. It is seldom that the same mining districts, almost never the same veins, yield copper and lead in abundance. One might venture to say, there is a peculiar elective attraction between sulphuret of lead and limestone rock; and this idea, followed too far, leads to the doctrine of the metallic contents being secreted from the bordering rocks. The materials of the veins seem indeed in many instances to have been transferred by (electric) currents through solid substances, but they are really diffused *from* the veins into cavities of the neighbouring rocks, not collected from these *into* the vein fissures.

Most of the veins of fissure are accompanied by dislocations ("faults"), sometimes to the extent of several hundred feet, sometimes only a few inches. They pass through the

stratiform basalt of Northumberland and Yorkshire, and *yield ore in it abundantly;* but though the toadstone of Derbyshire does not, as was once imagined, "cut the veins off," they are only feebly traced through it. But this circumstance is not peculiar to the igneous rocks; often, and perhaps generally, the veins in a limestone district are greatly contracted ("nipped") and unproductive at the places where they divide the shales, and grow wider and more prolific in the limestones and thick gritstones. Pipe veins are of less frequent occurrence and inferior interest. Ecton is one of the most remarkable of these.

The same phenomena of some veins crossing and cutting through others occur in this district as in the older strata, and the same tendencies to peculiar directions are recognised; the bearing veins running generally east north-east, or nearly so, and the cross courses north by west, in the north of England and Flintshire.

DISTURBANCES OF THE CARBONIFEROUS SYSTEM.

After the deposition of this system, and before at least any considerable proportion of the superjacent rocks was formed, very extensive displacement happened in most parts of the surface of the globe where the carboniferous rocks had been deposited. Not that such displacements were limited in geographical extent to the area of this system; on the contrary, from there hardly being a known coal tract exempt from this influence, it would appear that convulsive movements took place of a very general description, so as to affect very large tracts of the surface of the globe. In the British islands, every coal district is disturbed and shaken in every square mile of its breadth by faults ("gauls, slips, troubles, and dykes"), passing in

many directions, some of them having a great amount of "throw," and consequently affecting the working of the mines. But these minor effects, though on some accounts very interesting, lose their importance when we contemplate the gigantic disruption of Tynedale, the Penine chain, the Craven fault, the Derbyshire elevation, the fault of the vale of Clwydd, the double synclinal axis of the coal-fields of South Wales, and the parallel one of Namur. The Penine disruptions, ranked by De Beaumont under the title of the System of the North of England, are on a magnificent scale. Three principal lines compose this great system—the northern branch ranges along Tynedale from Brampton to the sea fifty miles, bending more than once from its average recticlinal course to the east by north; the southern branch passes in a straight line to the east-south-east thirty miles, and the two are connected by a line of fault, whose mean direction is nearly north and south, but it has three several courses in a length of fifty miles. The Craven, or southern branch of the system, is a double fault; the Penine line is partly an anticlinal and partly a fault; the Tynedale branch is one great fault. With reference to a point in the middle of the area, enclosed by these dislocations, their effect is everywhere similar, viz. a mighty depression of all the exterior country. North of the Tynedale fault, is a depression or throw of 1000 to 2000 feet; west of the Penine fault, 2000 or 3000, or perhaps 4000 feet under Crossfell; and south of the Craven fault 3000 feet at least under Ingleborough.

There is no direct connexion between this great Penine system of faults, and the elevation of Derbyshire; between them is a singular system of anticlinal elevations and synclinal depressions, all chiefly ranging north-east, or north-

east by east, from the Craven fault, right toward the more ancient but parallel anticlinals of South Wales. Before, however, reaching these lofty chains, a transverse break, almost exactly similar to the Crossfell fault, ranging north north-west, along the vale of Clwydd (which is a miniature copy of the vale of Eden), stops the Ribblesdale system of anticlinals in the south-west, just as the Craven fault, ranging west north-west, has stopped them on the north-east. It is from nearly the middle of the Ribblesdale faults that an anticlinal ridge, ranging south south-east, passes along the western border of Yorkshire and continues into Derbyshire, on the southern side of which county it is apparently cut off by an east and west fault.

Charnwood Forest is an elevation of slate rocks (on an axis of sienitic rocks), and the date of its elevation is posterior to the limestone and coal-field of Ashby, but anterior to the new red sandstone system, which is seen to lie level over its vertical and broken slates. The other central coal-fields of Warwickshire, Staffordshire, and Shropshire, were dislocated at about the same or perhaps somewhat later period, for the magnesian conglomerate is disturbed by the faults of the Coalbrookdale-field. From this field to the Malvern Hills, a great north and south axis of violent elevation occurs, which in places actually overthrows the strata (Murchison in Geol. Soc. Abstracts), and others proceed south-west, parallel to Wenlock Edge, till they reach the vale of the Towey.

Here a new axis of dislocation becomes predominant, that of the South Wales coal-field, which runs east and west from St David's in Pembrokeshire, through the counties of Caermarthen, Glamorgan, and Monmouth, and may be considered to continue into the Mendip Hills and Somerset-

shire. Parallel to this, and in fact in the line of its prolongation to the east, is the coeval disturbance of the coal from near Boulogne through Belgium and Westphalia, and in the south of Ireland. A parallel but perhaps earlier disturbance ranges along the northern boundary of the greywacke region.

It would be impossible here to investigate all the bearings of the mass of evidence furnished by these variously directed dislocations, on the dynamical principles of geology, but they are too important to be overlooked. We may, however, observe, that dislocations of different dates are thus shewn to be parallel, while others presumed to be coeval range in different directions.

STATE OF THE GLOBE DURING THE CARBONIFEROUS PERIOD.

Recollecting the proof already given of the partial elevation of our present dry land, we shall be prepared for considering the nature of the new conditions introduced into the geological formula, by this circumstance, and the variation of surface temperature, already concluded to be admissible as a geological cause. The Grampians and other mountain chains being raised above the sea, and shore and deep sea currents established, we shall not be surprised to find the traces of mechanical movement in the ocean suddenly grow very strong and extensive. We find, in fact, round all the mountain ranges, which for other reasons were presumed to have been uplifted before the carboniferous epoch began, some of the most remarkable conglomerate rocks which occur in the British strata. The character of these conglomerates, too, varies in direct relation to the proximity of the mountains. The composition of the

red conglomerates of the Grampian borders reminds us continually of the rocks of the Highlands; those which surround the Lammermuir Hills are full of pebbles derived from these mountains (Boué); those which border the Cumbrian group contain pebbles of the neighbouring rocks.

What is the cause of the universal red colour of these ancient sediments, is already felt to be an important problem, for it appears connected with absence of organic exuviæ in more than one instance. Shall we say that the local accumulation of the old red conglomerates was a consequence of the local elevation of the primary strata from the bed of the sea?

During the course of the carboniferous period the sediments of the sea underwent a total change, for red sandstones and clays are scarcely seen (except locally) among the coal-measures, or in the upper parts of the mountain-limestone series. Shall we say that the dark shales and variously coloured grits came from regions in different directions? The great quantities of those sediments imply, probably, some great physical changes of land and water in situations not far removed. The alternation of these deposits marks periods of intermitting action, and the circumstance of the prevalent association of terrestrial exuviæ in these, but not in other strata, seems to instruct us that the earthy and vegetable materials were swept down from the land by some such means as a great river or periodical inundation. If so, the origin of coal and that of the accompanying characteristic rocks (or "coal-measures") is understood, the regular thickness and extension of the strata of coal are ascribable to the watery agitation, which at once permitted the association of similar earthy particles into shale and sandstone respectively, and collected the vegetable masses into layers.

De Luc's notion of the origin of coal from submerged peat beds is too limited and encumbered with inextricable difficulties to be ever adopted as a general doctrine, nor can the minor analogies observed between the position of the subterranean mass of vegetables, the vertical trees, and (often imaginary) roots and branches, be held at all conclusive. What can be thought of an hypothesis such as that just named, when we try to apply it to a case like a north of England coal-field, with its numerous parallel seams of coal, ironstone, &c. for every one of which seams the land must first have been dried and covered with soil, then submerged to receive oceanic sediments; no fault, no want of conformity in the stratification, no unusual violence of water being in any case observable to justify the hypothesis of rising and falling land? Again, will it be supported for a moment in a country where limestone, shale, gritstone, coal, are repeated many times (as in the dales of the north of England); yet where the grits and shales vanish, every trace of coal also disappears? If there be *any* truth in the hypothesis, coal should be found in the midst of the limestone as well as enclosed in gritstone or shale; some independent proof should be given of the rising and sinking being limited to certain tracts; or some *reason* assigned for the dependence of coal on the occurrence of such sedimentary rocks.

It is evident that the general arguments must prevail, and the condition of the plants which compose the coal, the general absence of roots, the fragmentary state of the stems and branches, the dispersed condition of the separable organs, the splitting and reunion of coal beds, all the phenomena, in fact, really general, confirm the conclusion that the plants whereof coal consists were swept down from

the land on which they grew by watery currents, often repeated, and deposited in basins or large estuaries of the sea, or, perhaps rarely, in lakes of fresh water. The alternation of a bed of marine limestone in the Yorkshire coal-field, and perhaps the broad layers of bivalve shells (Unio), which appear sometimes in positions indicating that they lived and died where they are now found, shew an estuary deposit liable to temporary predominance of salt water. In the coal-fields of Shropshire and Manchester, the supposed fresh-water limestone may perhaps be ascribed to the influx of a river, and other coal deposits probably have happened in the deep sea at intervals during the accumulation of limestone.

What, then, were the circumstances of the dry land favourable to the growth of the enormous mass of vegetable substance which is buried in the coal formation? That the atmosphere was warmer, and, by consequence, moister, may be easily admitted, and in fact what is known of the structure of the plants goes to confirm this opinion; for the most abundant forms are at least analogous to tropical vegetation. But in addition, it has been conjectured that the atmosphere might in those early periods have an unusual dose of carbonic acid gas, and thus be more fit to supply the carbon requisite for the growth of such vast forests as then must have encumbered the limited surface of the land. This speculation of Brongniart appears worthy of attention; nothing known to the chemist or natural philosopher is opposed to the notion that the quantity of carbonic acid gas in the atmosphere may be extremely variable; it would not indeed be favourable to the life of animals, but *what proof have we of the globe being then tenanted by terrestrial animals?* Moreover, speculation apart, let

any one calculate the quantity of carbon contained in a single English coal-field, once a part of the living structure of plants, and add the equivalent volume of carbonic acid gas to that small quantity which it now holds, the consequence will be an atmosphere charged with this pabulum of vegetable life, to a degree perhaps very favourable to the growth of plants, but certainly detrimental to the life of animals breathing by lungs. Now, surely, it is worthy of attention, that *after the coal was deposited*, reptile life began to be manifested, and finally, to predominate; while, on the other hand, vegetable life, though the land was much more extensive and apparently not much lowered in temperature, never yielded again such thick and extensive carbonaceous deposits.

From the nature of its numerous organic contents, as well as from the texture and composition of its masses, there is no doubt of the mountain limestone being truly an oceanic deposit, diminishing and growing debased toward the shores, but accumulating in masses of greater purity toward the deeper seas. It appears to have been a chemical precipitate, more or less tranquilly produced; and if we may venture here to combine the facts known concerning the primary and secondary limestone, it will appear the most probable inference, that a slow decomposition of the oceanic waters, partly by organic, partly by chemical action, is the true cause of the production of marine limestone.

NEW RED SANDSTONE SYSTEM.

Geographical Extent.—The irregular expanse of sea left in the region of Europe by the broken masses of land, belonging to the uplifted carboniferous rocks, was perhaps not fully filled by the next succeeding deposit of sandstones,

clays, and limestone, which receives the name of Red Sandstone, or Saliferous or Pœcilitic formation, but it is very extensively diffused in and beyond this area. It occurs in Ireland, but not abundantly, and only in the north eastern part, which may be viewed as a dismemberment from the Lammermuir district of Scotland. In Arran, and on the west coast of Ayrshire, on the south side of the Lammermuirs, round Dumfries and Longtown, is a large tract of these rocks, spreading into the plain of Carlisle, the vale of Eden, and against the west face of the Cumbrian mountain limestone. Small detached parts occur farther south on the same side of the Lake district, and still smaller on the east, about Kirby Lonsdale.

But the greatest expansion of these rocks in England begins in Durham, about the mouth of the Tees, spreads southward in a narrow tract along the vale of York to Nottingham; then opens at once into the wide central plain of England, and occupies the whole breadth from the carboniferous tract of Lancashire, North Staffordshire, Derbyshire and Nottinghamshire, to Shrewsbury and Worcester, to Leicester and Shipston; then following the Severn to Bristol, it turns to the west along the south face of the South Wales coal-field, and is, interruptedly, continued south from the Bath Avon to the mouth of the Exe.

On the continent of Europe it occupies some space on the left bank of the Rhine in the district south of the Ardennes, and parallel to the Vosges; but on the right bank it is expanded over larger breadths in Wurtemberg, and occupies a great part of that enormous area included between Basle, Amberg, Leipzig, and Minden.

Almost universally it fills a low or level country, out of which arise insulated groups and short ranges of mountains

of older strata or pyrogenous rocks. Such are Charnwood Forest, and the central coal-fields of England; the Vosges, Schwarzwald, Thuringerwald, Odenwald, Harz, &c., in Germany. Its highest point in England does not much exceed 800 feet above the sea.

Succession of Strata.—This system consists of many alternations of arenaceous and argillaceous members, with some less continuous interpositions of limestone, usually impregnated with magnesia. The best types of the system are those of Germany, the south-east of France, and north of England. The most complete in all respects is that of Germany; but it will be convenient to describe the English series, and afterwards to present a general conspectus of the whole. It is to Professor Sedgwick (on Magnesian Limestone, Geol. Trans.) that we owe the most successful classification for England; and the labours of Voltz, Elie de Beaumont, &c., have ascertained all that is required for drawing the lines of geological contemporaneity between England and Germany.

Upper red sandstone formation.—Consisting of variegated red, white, and other clays, with gypsum; (organic remains, few and local). Red and white sandstone, with or without layers of clay; (few or no organic remains). Red conglomerate of pebbles derived from older rocks, imbedded in red sandstone; (no organic remains).

Magnesian limestone formation.—Consisting of upper laminated compact limestone of a light or dark grey or smoky colour. A few organic remains.

Gypseous red and coloured marls.

Lower or magnesian limestone, of a yellow colour, earthy,

granular, crystalline, or concretionary in texture, and (locally) organic remains in considerable abundance.

Marl slate or calcareous laminated rock, yielding fishes of the genus Palæoniscus chiefly.

Lower red sandstone formation.—Red and yellow sandstones with (locally) red and coloured clays, and plants like those found in the coal series.

The usual arrangement adopted in England unites the lower red sandstone, with the magnesian limestone formation. It is of little importance, however, whether we conceive the whole system to be but one formation, or divide it into two or three. On the western side of the north of England (Plain of Carlisle), the upper red sandstone retains its usual character; the magnesian limestone is represented by a calcareous conglomerate. Further south near Manchester, red and greenish marls and concretionary limestones, both fossiliferous, divide the upper from the lower red sandstones. In the centre of England (Cheshire, Worcestershire) salt rocks and springs occur. In all the southern districts (Shropshire, Gloucestershire, Somersetshire), a calcareous conglomerate represents the magnesian limestone, and the lower red sandstone is only locally seen. In the district south of the Ardennes, and along the Vosges, there is no magnesian limestone, but in the midst of the variegated marls lies a thick limestone rock (muschelkalk), in some respects comparable to the upper laminated limestone of the north of England, but containing many and different organic remains. In the variegated clays above the muschelkalk, is a thin bed of magnesian limestone; with this series of variegated clays is associated a variety of sandstones locally rich in plants, the whole group being in France called "marnes irisees,' in Germany, 'keüper'.) The red grit of

the Vosges (Grès Vosgien, Volz) is rather a local rock peculiar to that district, than a part of the lower red sandstone, which does, however, occur there beneath it. But in the Thuringerwald and north east of Germany, in addition to these, we have limestones corresponding to the upper and lower magnesian limestone, gypseous marl, and marl-slates of England, under the general name of Zechstein. Thus the whole is capable of being represented in one formula, which is well calculated to shew both the agreements and differences usually observed in comparing distant parts of a stratified formation.

North-east of Germany.	The Vosges.	South of England.	North of England.
Keuper sandstones and marls.	Marnes iriseees.	Variegated marls.	Variegated marls.
Muschelkalk.	Muschelkalk.		
Bunter sandstone.	Gres bigarré.	Red and white sandstone,	Red and white sandstone and conglomerate.
Zechstein.		Calcareous conglomerate	Magnesian limestone.
Rothetodteliegende.	Gres Vosgien gres.		Lower red sandstone.

Salt is associated with the upper parts of this system in England, France, and Germany, where the muschelkalk is quite as saliferous as the variegated marls, to which apparently salt is confined in England. Upon the whole, then, this red sandstone system is a vast mass of sandy and argillaceous sediments of a peculiar aspect, accompanied more than any others yet known by salt and gypsum,—generally deficient in organic remains, and only locally inclosing strata of limestone, which commonly are characterised by abundance of magnesia.

In the north of Germany the lower beds of it seem de-

cidedly related to the coal deposits, (as also happens in the north of England); in fact, the coal is supposed by Hoffman to be only a local product in a vast mass of red rocks, including the whole series of the old red and new red rocks. Nearly the same thing takes place in Arran where the diminished carboniferous system is merely a parting in the enormous thickness of red clays, sandstones, and conglomerates. Thus, it is evident that our best classifications of the series of stratified deposits can only be locally exact, and authors of such arrangements must be prepared to see them rejected, as in many cases inapplicable or very inconvenient.

Stratification.—The same laws of phenomena on this subject obtain in the red sandstone as in the carboniferous system; the argillaceous masses are laminated, often composed of alternating white, greenish, and red layers; the sandstones when very fine are also, in general, thinly bedded; where very coarse they are in ruder and less regular layers; where pebbles and sand are mixed (Nottingham Castle), the layers are oblique in various directions, like the heaps of detritus left by rapid rivers or other sudden violence of water. The limestone beds, if argillaceous, are thinly bedded; if magnesian, they are often thicker, less regular, full of sparry geodes, and strings and veins of carbonate of lime. These magnesian rocks are also often very concretionary, sometimes oolitic, in particular parts (Mansfield, Nottinghamshire) composed of real crystals of the double carbonate of lime and magnesia. Some beds have a conglomerate character, and in such, generally, stratification is almost imaginary, and the joints which pass through the other beds, lose themselves without penetrating this. (Shields and Sunderland.)

Organic Remains. South of a line drawn through Chester and Derby, organic exuviæ of plants or animals have been rarely found in the red sandstone system of England; none have yet occurred in that of Scotland; but fishes have been discovered in that of Ireland. (Report of Proceedings of British Association at Dublin, 1835.)

In the space north of this line it is only on the western side of the island that plants have been found in red sandstone, near Liverpool (See "Fossil Flora, 1836), marine shells (conchifera and gasteropoda) lie in the red and white marl, and calcareous bands near Manchester. On the eastern side of the island the lower magnesian limestone is nowhere entirely destitute of shells and zoophytes, which have often a great analogy to those of the carboniferous rocks: the upper laminated rock has also a few shells, the lower red sandstone many plants.

In Germany, the rotheliegende, zechstein, bunter sandstein, muschelkalk, and keuper, all contain organic remains, and locally even in considerable quantity.

No complete list of the fossils of the English magnesian limestone has ever been published. Professor Sedgwick, however, (Geol. Trans.), mentions a considerable number of the Durham fossils, and M. Agassiz has recently added to the list of fishes. The following summary includes some nondescript species now in the cabinet of the writer.

Plants	Voltzia, one species.	
Zoophyta, .	Polyparia, ...	3
	Crinoidea, ...	1
Conchifera, .	Plagimyona, ...	9
	Mesomyona, ...	6
	Brachiopoda, . . .	15

Gasteropoda,	4
Cephalopoda,	2
Fishes,	10?
Reptiles,	2 or 3

Igneous Rocks.—Basaltic dikes divide the magnesian limestone of the north of England; and in the Island of Arran (Jameson, MacCulloch, &c.) such and other dikes of pyrogenous rocks and interposed beds are extremely abundant in Corygills, at Tormore, and other points. Nothing of the kind is found in the greater part of the English red marl and sandstone; but the analogous red conglomerates and porphyritic masses of Exeter (investigated by De la Beche), appear important, as throwing light on the analogous, if not strictly coeval, mixtures of porphyritic and arenaceous rocks common in the north of Germany.

It is chiefly by the occurrence of porphyritic fragments and pebbles that the mixture alluded to takes place near Exeter; it appears a natural supposition that, in the confined accumulation of the red conglomerate from the action of violent water-currents, consequent on local displacements of the crust of the globe which followed the deposition of the coal-measures, some of the broken masses of igneous rocks should be retained among the materials then aggregated. In fact, the country was dislocated near the conglomerate of Exeter; and Mr de la Beche notices circumstances tending to shew that the porphryitic eruptions did happen, and sometimes overflowed parts of the conglomerate while it was in process of accumulation.[1]

On the east side of the Harz the red sandstones and marls (of the Rotheliegende) rest on a porphyritic conglomerate, of which the porphyritic fragments are not always si-

[1] *Proceedings of Geological Society*, 1834.

milar to the nearest quartz porphyry of Saal, often being larger in proportion to the distance therefrom. This conglomerate is regular and widely expanded, and none of the other beds of the red formation contain such porphyry pebbles. (Von Dechen).

Thus, it appears certain that the detritus of igneous rocks (generated, it appears, in Devonshire at the same era) furnished the materials of the lower beds of the Rotheliegende ; and we may perhaps hereafter be able to form a conception as to the extent to which igneous eruptions, and wasted igneous rocks, may have modified the characters of the deposition of the whole system, which, in mineral, structural, and organic characters, offers much that is worthy of notice, and very alluring to imprudent theorists.

Metallic veins are, in England, very rarely heard of in these rocks, nowhere worked. Lead veins occur in the marl-slate near North Shields,—in the magnesian-limestone at Nosterfield, and Warmsworth, Yorkshire, and Barlborough Derbyshire ; carbonate of copper is found at Farnhill near Knaresborough, Newton Kyme near Tadcaster, and Warmsworth ; cobalt is found in Alderley Edge, Cheshire.

In Germany the slaty beds, which are the equivalent of the marl-slate, are loaded with copper about the Harz Mountains, and contain fishes. They receive the name of kupferschiefer.

DISTURBANCES OF THE RED SANDSTONE SYSTEM.

The most remarkable example is on the eastern face of the Vosges Mountains, where the upper beds of the system lie at the foot of great precipices of the Gres Vosgien. In England almost nothing of this kind is observable. The magnesian limestone is divided and dislocated by some of

the faults and basaltic dykes which traverse the coal of the Newcastle district. One of the anticlinal lines west of Shrewsbury, which ranges from west south-west to east north-east, through the Breiddin Hills, has been noticed by Mr Murchison as continuing in a narrow course through the red sandstone of the plain of Shrewsbury, and directing itself toward the elevated coal and gritstone hills near Cheadle. The red sandstone along this line (at points fifteen or thirty miles from the Breiddin), is thrown into angular positions, altered and impregnated with metallic substances; and dykes of trap occur at Acton Reynolds. The most curious inference on the subject is, that the same line has been the locus of igneous eruption and disturbing movement during the silurian, carboniferous, and red sandstone eras, a conclusion singularly at variance with the literal statement of De Beaumont's hypothesis, though, as being a solitary instance, it ought not to be too much insisted on. It appears from the same author and Mr Prestwich, that some of the most considerable dislocations of the border of the coal-fields of Coalbrookdale and Dudley happened after the deposition of a part of the new red sandstone; but it is certain that those of Somersetshire and Gloucestershire were completed before the date of that rock.

STATE OF THE GLOBE DURING THE FORMATION OF THE NEW RED SANDSTONES.

The greater extent of land, as indicated by the uplifting of many portions of the coal deposit, might have been expected to have caused greater local varieties in the composition of this system than we find. In fact, as a general rule, the traces of terrestrial admixture in the red sandstone deposits are remarkable, and unusually few. The shells

and other organic exuviæ are marine; and it is only in a few places round particular mountain ranges (the Black Forest especially), that the remains of land plants and reptiles are at all prevalent. Several reasons might be adduced to justify an opinion, that the time occupied in the production of the whole system was comparatively short,—such as the general uniformity of its composition, the deficiency (except in limited regions) of limestones; the peculiar chemical and mineral character of these limestones; the general paucity of organic remains; the frequency of conglomerates and local admixture of fragments of igneous rocks,—all these circumstances seem to indicate the prodominance of an unusual series of agencies.

A notion has gradually been spreading, though it has perhaps not been distinctly announced, that many of these circumstances are the result of temporary volcanic excitement consequent upon the deposition of the coal-measures; but it is difficult to collect adequate reasons from the vague data at present known, for clothing this suggestion with the substantial character of a probable inference.

Concerning climate and other circumstances, the evidence from remains is of little value; but their analogy with those of the carboniferous system leads to the impression that no remarkable changes had occurred in this respect.

OOLITIC SYSTEM.

Geographical Extent.—In the British islands, and, we may add, in the continent of Europe, this mass of calcareous rocks is very unequally distributed, yet in particular regions its course is very persistent, and the different formations which compose it follow one another with remark-

able conformity. Scarcely any traces of it occur in Ireland, except in the north-eastern part, which contains the chalk and red sandstone. It is found on the east coast of Scotland at only a few points about the Moray Frith, and along the Sutherland coast. On the western coast it occurs at Applecross, opposite to the Isle of Skye, and at several points in that island, and some of the smaller islets adjacent. In the same manner, it borders Mull, and is found skirting the mainland along the Sound of Mull.

But in none of the Irish or Scottish localities is the system completely, or even characteristically, exhibited; it is, in fact, more properly an English than a British system of strata, and there are few tracts of Europe where it is more expanded or so fully and variously developed. From the prominent parts of the Yorkshire coast, between Redcar and Filey, it holds an uninterrupted course, with varying breadth, through Yorkshire, Lincolnshire, Northamptonshire, Oxfordshire, Gloucestershire, Somersetshire, and Dorsetshire, to the southern coast between Exmouth and the Isle of Purbeck, almost everywhere forming a rather high table-land and dry surface, sloping regularly to the east, and dividing the eastern and western drainage of the island. It is nowhere narrower than in a part of Yorkshire near Bishop Wilton, where, in consequence of unconformity of the chalk, only the lower part of the lowest member is seen, and its breadth is only a few yards.

On the contrary, in the middle of the island, as in the counties of Northampton, Rutland, Gloucester, and Worcester, its breadth is even as much as forty miles. Toward the western edge, which is generally a line of bold escarpement, many outliers, or detached masses, occur, separated by watery violence or other causes. Of these the most

singular and far removed is the newly discovered basin of lias (the lowest of the oolitic formations) in the centre of the red marls and sandstones of Cheshire.—(Geol. Proceedings, 1835). Other extensive outliers follow the southern border of the South Wales' coal-field far into Glamorganshire.

On the continent of Europe the oolitic system is widely expanded; in France in a large semicircle round Paris, from the Ardennes to Normandy. It has a long range in Wurtemberg and Franconia; occurs in places along the range of the Carpathians (Poland), and margins, with a broad band, the north and south slopes of the Alps. It is supposed to enter into the composition of the Apennines, and the Dalmatian ridges, and to form a part of the limestone ranges of Spain, perhaps also of Greece.

The skirts of the Himalaya certainly contain at least its lower members, and perhaps these are not wholly unknown in North America.

Succession of Deposits.—There are three principal types of the oolitic system in which its developed characters appear considerably unlike; and it seems possible to ascertain the proximate influences or causes of the diversity. The series of oolitic rocks near Bath was the first field of the successful researches of Mr Smith in analyzing the secondary strata and determining the relation of organic forms to the successive stages of geological time. The excellent and exact arrangement which he here disclosed is the true fundamental standard of comparison for all the localities, not so much on the account of its being chosen by Mr Smith, as because it is in fact the most complicated (that is most fully expanded or developed) series of this system yet

known. The following classification will be found very convenient for the Bath district.

Names and Description of Formations.	Constituent Groups
Wealden Formation: a mass of sandstones and clays of various descriptions, irony, calcareous, carbonaceous; with layers and nodules of limestone, generally bearing the aspect of a fresh-water or estuary deposit, ...	*x*. The Weald clay. *w*. The Hastings sand. *v*. The Purbeck beds.
Upper Oolitic Formation: here imperfectly seen; composed of oolitic and other limestones, green and irony sands, and blue clays of considerable thickness, with organic remains. Composed of . .	*u*. Limestone of Swindon, the Vale of Wardour. *t*. Sands of Swindon, and *s*. Clay of the Vale of North Wilts.
Middle Oolitic Formation: consisting of coralline and shelly oolites, calcareous sandstones and clays, with organic remains, . . .	*r*. Thin calcareous grit. *q*. Coral rag and oolite. *p*. Calcareous grit. *o*. Blue clay and septaria. *n*. Kelloway sandstone. *m*. Blue clay.
Lower Oolitic Formation: a complicated group of oolitic and shelly and sandy limestones, laminated and concretionary sandstones, sandy and tenacious clay, fullers' earth, &c.	*l*. Cornbrash limestone. *k*. Forest marble group. *i*. Bath oolite. *h*. Fullers' earth rocks. *g*. Superior oolite, and *f*. Sandstone.
Lias Formation: chiefly argillaceous, with strata of limestone, all more or less argillaceous, but rarely oolitic; layers of sandy irony rocks, and septaria; abundance of organic remains, . . .	*e*. Thin upper lias clay. *d*. Marlstone rocks. *c*. Middle lias clay. *b*. Lias limestones. *a*. Lower lias clays, generally passing to new red marls.

Upon further examination in the country south of London, it is found that a superior formation (the Wealden) exists very extensively in Kent and Sussex, and this, for

the sake of making the Bath series general for the south of England, has been placed in the above scheme of five oolitic formations.

In this alternation of limestones, sandstones, and clays, we behold deposits effected in periods of alternating disturbance and quiet, such as might happen not far from the shores of the ancient sea; and in the uppermost formation, the effects of agitated water predominate.

The next type, taken from Yorkshire, shews these littoral effects carried to extreme, in some parts of the sea, *but not in others.* The following is a short view.

The Wealden Formation.		Unknown in the North of England.
The Upper Oolitic Formation, represented only by		*s.* Thick clay.
The Coralline Formation is composed nearly as in the south of England, . . .	Upper group,	*r.* Upper calcareous grit. *q.* Coralline oolite. *p.* Lower calcareous grit.
	Lower group,	*o.* Oxford clay. *n.* Kelloway sandstone. *m.* Thin blue clay.
The Lower Oolitic Formation is very different from that of Bath in detail, .		*l.* Cornbrash limestone, thin. *k*? Sandstones and clays, with land plants, thin coal, &c.; calcareous sandstone, or sandy, concretionary, shelly limestone. *i*? Oolitic limestone, thin. *h*? Thick mass of sandstone (often carbonaceous) and clays, often full of plants, with coal-beds and ironstone. *g* Irony and sandy limestone. *f.* Sand, and concretionary limestone.

The Lias Formation is very similar to that of the south of England, and by adding the lower members from the Lincolnshire section, the whole is a more fully expanded series than that near Bath	e. Upper lias shale (alum shale). d. Marlstone, sandy and calcareous layers. c. Middle lias shale (lower shale of Yorkshire coast). b. Lias limestones of South Yorkshire and Lincolnshire. a. Lower lias clays of the Trent-side (graduating to the red marls below.)

The oolitic series of Sutherland and the Western Isles of Scotland, investigated by Murchison, agrees nearly with the Yorkshire type: so does that of the whole northern line of Westphalian oolites, from Bramsche, by Minden, to Wolfenbüttel and Helmstadt, but the greater part of the continental oolites form a series analogous to that of the south of England. In Normandy there are almost exactly the same groups (M. de Caumont). On the south of the Ardennes (M. Boblaye), the clays of the English series grow less conspicuous, but the *series* is similar. In Burgundy (M. de Beaumont), the calcareous character of the group augments, and the argillaceous members diminish, so that the several oolitic formations become more difficult to define than in England. The same is true in a still more decided degree on the border of Switzerland; in Wurtemberg and Franconia; and generally along the borders of the Alps.

The general result of all this is, that the type of the oolitic system of the south of Europe is more calcareous; that of the north of Europe more arenaceo-argillaceous. The former has the air of an oceanic or deep-sea deposit, little disturbed by currents of water; the latter was accumulated

under the predominant influence of littoral agitation. In most cases, indeed, but not universally, the specially argillaceous lias formation is distinguishable (even among the Alps and around Auvergne) from the specially calcareous upper oolites; the middle part of the system (Bath oolite formation) is the most variable, and the uppermost formation (Wealden rocks) is merely local.

Organic Remains.—It is impossible to say with certainty over what extent in extra-European countries the oolitic system spreads, because of the great alterations which mixed secondary rocks experience near the axes of mountain elevation. Thus the description of the thick limestone overlying red sandstones, on the banks of the Lakes of Como and Lecco (De la Beche, *Geol. Manual*), would be insufficient to make us recognise the oolitic system, but for the additional evidence afforded by certain fossils. The lias of the Swiss and Austrian Alps could not be satisfactorily understood without their aid (Necker and Murchison's Notices); nor could the singular alternations of granular limestones, micaceous slate, &c. of the Tarentaise (M. Brochant), and the problematical rocks of Piedmont (M. De Beaumont), be referred to the lias, but for the belemnites which occur abundantly among them. It is true, that here a singular anomaly occurs with respect to the organic remains, for the belemnites of the lias are found both above and below a great number of plants analogous to those of the ancient coal-measures! But this ought not greatly to surprise us. There is nothing known in geology which should forbid an admission that particular localities *of land* might enjoy an immunity from the effect of those causes which wrought periodical changes in the physical conditions and organic inhabitants *of the sea.*

The plants of this anomalous series may be viewed as a remainder of the vegetation of the era of coal deposits, transferred to a sea full of organic beings of the earliest oolitic era.

The importance justly attached to the study of organic exuviæ has been overrated by some of the followers of Mr Smith, and wholly misunderstood by some of the opponents of his views. We, who have known intimately the principles really advanced and acted on by that distinguished man, may be permitted to say this, and to shew what is really their nature and meaning, by investigating their application to the geological history of the oolitic rocks, the consideration of which undoubtedly suggested the whole doctrine of the identification and discrimination of strata by their imbedded organic " remains."

The local truths ascertained by Mr Smith with respect to the oolitic rocks in the neighbourhood of Bath, as appears from his works, "Stratigraphical System" and "Strata identified by organized Fossils," are these, the nomenclature being made to suit the modern arrangements:

(1.) The fossils of the oolitic system as a group, viz. the plants, zoophyta, shells, crustacea, and fishes, differ completely from the fossils similarly grouped of the cretaceous system above, and the new red sandstone and coal systems below.

(2.) The organic remains of the lias formation differ, as a group, almost absolutely, from those of the Bath oolite formation, and these present points of less general difference from those of the coralline oolite formation. Thus all the formations have characteristic local distinctions in their organic remains.

(3.) Many of the individual rocks, or masses of analo-

gous beds and layers, contain particular characteristic fossils, which never or rarely occur in other rocks.

(4.) The fossils of strata the most similar in their mineral nature, as the oolite rocks,—the sandstones,—the clays,—are more frequently similar or identical than those of rocks differing in nature. Thus the same, or similar echinida, occur in the Bath oolite and the coralline oolite; similar, if not the same grypheæ occur in the lias clays, the Oxford clay, and the Kimmeridge clay.

These *local truths* are found to be applicable in all situations where the oolitic series is expanded; they are repeated on the Yorkshire coast (Geol. of Yorkshire), on the west of Scotland (Murchison), (Dorsetshire (De la Beche), in Normandy (De Caumont, &c.), south of the Ardennes (Boblaye), in Central France (Dufrenoy, &c.), in Franconia (Munster), in the south-east of France (De Beaumont, Voltz, &c.).

In generalizing these local truths Mr Smith found that, for a considerable distance north and south, the fossils of the oolitic system, as a mass (1.), were almost universally similar, and generally the same, but universally distinct from those of older or younger systems.

(2.) That the distinction of the several oolitic formations was practicable for considerable distances by the same species, or groups of fossils, which characterized them near Bath.

(3.) That the several rocks contained, at great distances, many of the same fossils which occurred in them near Bath.

Hence arose the impression that, in England, the oolitic and other strata of the same age contained the same or similar organic bodies. It was not possible for Mr Smith

to state his laws as general principles universally applicable, because, originating in observation, generalized by observation, they were in no sense hypothetical;—they were inductive not deductive,—limited to things known, not extended to things unknown.

In following out Mr Smith's views, it has been found, that the proposition (1.) of the entire distinctness of the whole group of oolitic fossils from the older and newer fossils, is almost universally true; the exceptional cases mentioned along the range of the Alps, being, in fact, viewed as singular and difficult anomalies. It has also been found, that mineral masses of most contrasted types, as the argillaceous lias compared to the calcareous oolites, retain the same general features of distinction in organic remains, wherever they have yet been examined. Whole groups of the same belemnites and ammonites mark the lias of Yorkshire, Dorsetshire, and Wurtemberg. It has also been found that the geological place of several of the species selected by Mr Smith as characteristic of Bath rocks, is the same, or nearly so, in very distant situations (Apiocrinus rotundus, Cidaris florigemma, Avicula echinata, Terebratula digona, Ostrea delta, Gryphæa dilatata, Ammonites calloviensis, &c.); but it is also certain, that the number of these characteristic or *monochronic* fossils is continually diminishing; that the influence of geographical position is more important than was at one time imagined; that varying physical conditions exerted corresponding influence over the distribution of organic forms; that each species had a definite range of organic existence; and, finally, that identity of species is not often to be looked for at very great distances, though a remarkable general analogy and similarity of form appears still to be very ex-

tensively recognised in the same formation at every point of its range.

The abstractions used in zoological science,—the combination of species into smaller groups,—and these into larger families, are now so much improved, that the seeming complication of the results of the study of the thousands of fossil species is fast disappearing. Whole sections of fishes, ammonites, and belemnites mark the lias, others the oolites, others the chalk, while groups of terebratulæ, gryphææ, &c. mark stages more or less definite in the scale of oolitic deposition. Where the rocks come to be aggregated together, the characters of division cease. On comparing distant regions, only the broader zoological features of the rocks can be employed with safety. On comparing contemporaneous rocks produced under different conditions, we find the effects of such conditions in the monuments of organic life; in the general conformity of organizations imbedded in contemporaneous deposits, we read the evidence of similar physical conditions over very large tracts of the globe; in the successive diversity of the organic types we see proof of the successive general changes of the conditions. Who will say that such results are unphilosophical, or inconsistent with Mr Smith's fundamental doctrine, that the successive strata were successively the bed of the sea, and contain the remains of the vegetable and animal creation then existing on the spot or in the vicinity?

The first column of the following summary of the organic remains in the oolitic system is taken from Mr de la Beche's Notes on the Geographical Distribution of Organic Remains in the Oolitic Series of England and France (*Phil. Mag.* 1830); the second column is compiled from

the last edition of his *Geological Manual* (1833); the third contains the number of species of oolitic fossils in Yorkshire, from the second edition of the *Geology of Yorkshire* (1835).

Vegetable Remains,	Marine, . .	1	3	1
	Cryptogamia, .	17	23	35
	Gymnospermia, &c.	21	26	12+
Zoophyta,	Polyparia, ...	49	172+	18
	Crinoidea, ...	8	32	5
	Stellerida, ...	2	11	1
	Echinida, ...	22	45	16
Mollusca,	Plagimyona, . . .	165	200	115
	Mesomyona, . . .	110	141	66
	Brachiopoda, . . .	50	66	23
	Gasteropoda, . . .	95	112	48
	Cephalopoda, . . .	138	258	83
Annulosa,	. . . . . .	15	59	10+
Crustacea,	. . . . . .	1+	15	9
Insecta,	. . . .	Several	...	...
Pisces,	. . . .	1+	22+	Several
Reptilia,	. . . .	16+	30+	7+
	. . . . . .	1	1	...
		712	1216	449

The deposition of the oolitic system seems to have followed upon that of the red sandstone rocks without the intervention of more than local disturbances; and it appears that, in general, few such occurrences broke the long uniformity of the periodical agencies exerted in the oolitic period. Mr Murchison has shewn that the elevation of the granitic mass of the Ord of Caithness, took place after the deposition of most of the oolitic rocks, for these are thrown into great confusion in the vicinity.

In the north of England, the only igneous rock found in connection with the oolitic system, is the great dyke which ranges from the mountain limestone near Middleton in Teesdale, through the coal-measures of Cockfield Fell; the magnesian limestone of Bolam, in Durham; across the

red sandstone of the Vale of Tees; the lias of Cleveland; and the inferior oolite, Bath oolite, and intervening sandstones and clays of Eskdale and the Moorlands, near Robin Hood's Bay. In this long course of seventy miles, the dyke retains so much of a common character,—its constituent basalt is so similar,—and the line which it describes so direct, that little doubt can be entertained of the contemporaneity of its whole mass. The effects which it has produced on the strata along the whole range are of the usual kind noticed near pyrogenous rocks: coal is charred; sandstone hardened; shale bleached and indurated. Nothing of the kind is known in the south of England.

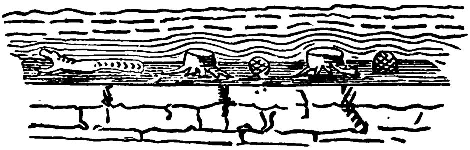
Disturbances of the Oolitic System. The disturbed state of the strata, accompanying the elevation of the Ord or Caithness, has been already noticed. In the north of England, the unconformity of the chalk and oolite indicates a low axis of elevation, passing east and west, under the Yorkshire Wolds; and other dislocations parallel to this occur in Eskdale and other parts of the Yorkshire oolites. A similar unconformity, and nearly equal amount of disturbance is found in the Dorsetshire oolites, where, besides, are great faults of a later date. In this district, however, phenomena have been observed in the Isle of Portland, leading to the impression that a limited tract of oolites had been raised into dry land, covered with soil and prolific in trees, and again quietly submerged, so that the trees were left standing in attitude of growth, or prostrate in "*the dirt-bed.*" This remarkable deposit has been observed by Mr Webster and other geologists; but it is to Dr Buckland and Mr De la Beche that we owe a full account of the circumstances and suitable reasoning concerning them.

"We consider a small stratum," say these geologists,

"called by the workmen 'dirt-bed,' to be by far the most interesting and remarkable deposit in the district. It

No. 13.

Section of the Dirt-Bed in the Isle of Portland.



seems to be made up of black loam, mixed with the exuviæ of tropical plants, accumulated on the spot on which they grew, and preserved during a series of years in which the surface of the Portland-stone had for a time become dry land, and accumulated a soil of about a foot in thickness, composed of an admixture of earth and black vegetable matter, interspersed with slightly rounded fragments of stone, which Mr Webster ascertained to be from the lower part of the Portland series. These fragments are found to be almost co-extensive with the 'dirt-bed,' and the fact that we have yet found with them no admixture of pebbles derived from the subjacent oolites, or from any other more ancient rocks, shews that no violent rush of water from any distant region took place during the period in which these pebbles of Portland-stone were under the process of becoming slightly rounded."

This dirt-bed, as Mr Webster has stated, forms the matrix of the silicified trunks of very large coniferous trees, which are so abundant in the Isle of Portland, and are found there coextensive with the upper surface of the Portland-stone. Wherever the dirt-bed is laid open to extract the subjacent building stone, it is found to contain these silici-

fied trees laid prostrate, partly sunk into the black earth, and partly covered by the subjacent calcareo-siliceous slate; from this slate the silex, to which the trees are now converted, must have been derived. A bed of snow falling on a modern peat-bog, and covering the upper portion of prostrate trees whose lower portion has been sunk by their weight into the substance of the peat, would represent the position of the calcareous slate which immediately covers these fossil trees in Portland.

Some of them extend to a length exceeding thirty feet, and bifurcate at their upper end; but the branches are not continuous to their extremities, and we find no trace of leaves. The leaves and small branches, and exterior parts of the trunks, had probably decayed whilst they lay exposed to air on the surface of the peat.

Amid the prostrate trees, many of which attain three or four feet in diameter, we find silicified stems of plants closely resembling the modern Cycas and Zamia; they have been described by Professor Buckland under the name of Cycadioideæ, and are important as indicating that the temperature in which they grew was higher than that of our present climate. We find also, at nearly the same intervals at which trees are found growing in a modern forest, an assemblage of silicified stumps or stools of large trees, *with their roots attached to the earth in which they grew.* These stumps are from one to three feet long; they are mostly erect, while a few are slightly inclined. The black earth which contains their roots seldom exceeds one foot in thickness; the upper portions of the stumps, as represented by Mr Webster, project upwards into the substance of the superjacent stone (called " soft burr" and " aish"), which gives indication of their presence by hemispherical

concretions accumulated around the top of each stump or wood.

The dirt-bed is found in several places near Weymouth, and is slightly traceable in the Vale of Aylesbury, at Swindon and Tisbury.

" We consider the dirt-bed as quite decisive in forming the barrier between the Portland (marine) and Purbeck (freshwater) deposits. Its accumulation must have proceeded during a considerable portion of time, antecedently to which the districts it occupies were entirely submerged beneath the sea, and subsequently to which the water again returned to overwhelm them, first with a deposit of about 1000 feet of the semilacustrine sediments of a great estuary (including the united thickness of the Purbeck series, and the Wealden sands and clays), and afterwards with a series of marine deposits, amounting to more than 1000 feet of greensand and chalk.

Throughout the entire succession of all these changes, there is no evidence of any sudden and violent disturbance causing either elevation or depression of the Portland-stone or of the subjacent oolites. The present high inclination of all the beds is uniformly parallel to that of the beds of Purbeck-stone, greensand, and chalk, and these all seem to have been raised simultaneously by the same convulsion which elevated the axis of the Weymouth district, together with all the inclined strata in Purbeck and the Isle of Wight.

We have a measure of the duration or the period during which the surface of the Portland-stone continued in the state of dry land covered with forest, in the thickness of the dirt-bed, which has accumulated more than a foot of black earth, loaded with the wreck of its vegetation. The

regular and uniform preservation of this thin bed of black earth over a distance of so many miles, shews that the change from dry land to the state of freshwater lake or estuary was not accompanied by any violent inundation or rush of water, since the loose black earth, together with the trees which lay prostrate on its surface, must inevitably have been swept away had any such violent catastrophe then taken place."[1]

Besides the true dirt-bed above described, Professor Henslow found two other argillo-carbonaceous layers lower in the rock: in one of the lower of these Dr Fitton has recently found stumps of trees of the same kind as those in the dirt-bed, apparently in the position and attitude of growth.

GENERAL VIEW OF CIRCUMSTANCES ATTENDING THE DEPOSITION OF THE OOLITIC SYSTEM.

With this example in our minds of the progress toward definite knowledge of the local conditions of land and sea during the oolitiferous era, we may turn to a general contemplation of the subject. It is apparent from the plants found in the lias of Dorsetshire, the Bath oolite and coralline oolite formations of Yorkshire, and the Portland and Wealden formations in the south of England, that land, to some extent, existed in several points about the region of the oolitiferous sea of Europe. The analogy of some of these plants to the tropical tribes of Zamia and Cycas, is sufficiently exact to warrant our belief in the analogy of the climate in which they grew; the case of the dirt-bed seems inexplicable except on the supposition of alternation of land and

[1] *Geological Transactions*, second series, vol. ii.

water without violence; a given large area was subject to gradual vertical rise and fall to the extent of 1000 feet or more, so that certainly once (perhaps thrice or more frequently), there was time allowed for the elevated bed of the sea to be covered with heaps of decaying vegetation, and the stumps of numerous large trees which it had nourished into dense forests. Can any thing more plainly teach the human intellect not to set narrow bounds to the TIME which elapsed in those numerous physical conditions which preceded the era of the creation of man and the present adaptation of the surface of the globe?

If *between* the aggregation of marine and fluviatile sediments of the Portland and Wealden formations, *the whole life of large and stately coniferous trees has elapsed*, who will revive the unworthy folly of ascribing the curious proofs of regular and orderly structure,—the rich monuments of physical changes which the earth offers to the eye of intelligent man,—to a sudden deluge or any other violent catastrophe? It is time that the blind opposition to the progress of inductive geology, based on an erroneous view of the true meaning of the Scriptures, derived from days of ignorance, should be wholly abandoned; and perhaps the consideration of *the proof* furnished in the Isle of Portland may be sufficient to relieve at least some of the unreasonable pressure which geology feels from sources where it should meet with hearty encouragement.

We do not at present concede that the equisetiform plants which stand erect in the sandstones between Whitby and Scarborough grew on the spot where they are now found; nor is it at all required to suppose that, in the Weald of Sussex, the vegetable reliquiæ were the produce of that very region; on the contrary, the manner of the occur-

rence of the plants in both these districts appears to prove that considerable tracts of land *in some other situations* were raised above the sea, and that rivers and inundations from this land transported materials of different kinds with a certain periodicity of action from more ancient strata. In what direction, from what ranges of uplifted land these rivers flowed, cannot perhaps be said; perhaps no land *now* above the waters yielded the sands and clays and calcareous layers to the Weald of Sussex, the moors of Yorkshire, the borders of Sutherland and Argyle, or the northern oolites of Westphalia. Yet some arguments might be adduced, especially the analogy of mineral composition, to shew the probability of anciently elevated coal strata having been the source of these sandy interpolations. At all events, they are composed of matter swept by fresh water from the land into lakes, estuaries, or the sea, for the plants and shells found with them permit no other inference. These, then, if marine, are littoral deposits; but the series of oolitic limestones, in which they form anomalous local and irregular terms, were certainly for the most part deposited in situations considerably removed from the agitation of coasts and the intermixture of fresh water. This their arrangement, freedom from conglomerates, perfection of organic contents, and simplicity of composition, fully prove. Particular beds undoubtedly (especially the top of the rocks) have suffered agitation.

The concretionary structure of these limestones is imitated in modern times only in situations where carbonate of lime is separated from chemical solution in water (Carlsbad). If we ascribe this origin to the oolitic sediment, the concretionary aggregation of the particles may be understood as arising from molecular attraction in the mass, and, in

fact, many of the spherules of oolite contain an internal nucleus of previously solidified matter, a small shell, a grain of sand, or somewhat else, capable of determining the condensation of the particles to particular centres, just as the matter of ironstone has collected into nodules round a fish-scale, a piece of fern branch, or a shell.

The periodical occurrence of clays, sands, and limestones is not less remarkable in some parts of the oolitic system than in those of older date; the Bath oolite formation is sandy at the base and sandy at the top; the coralline oolite has superior and inferior sandstones, and the same is the case with the Portland oolite where the series is complete, (Vale of Aylesbury). The clays of this series appear to be in a considerable degree independent of the compound terms (of limestone and sandstone), and thus furnish means for an easy and natural division of the English oolites, which fail in various parts of southern Europe.

CRETACEOUS SYSTEM.

Geographical Extent.—In general we may perceive, as the several systems of strata pass under review, that the areas which they respectively occupy are defined by narrower boundaries, and that these approximate more and more to the present distribution of the basins of the sea. The north-eastward ranges of the oolitic strata of England, sloping gently to the east and south-east, are covered on their declining surfaces by ranges of chalk and greensand, which nowhere ascend to so great heights as the oolites which rise from beneath them. The cretaceous system is unconformed to the oolites at only two points in England, viz. in Yorkshire and Dorsetshire, and round the basin of

Paris and in the south of France the same conformity of the two systems is found to prevail.

It thus becomes easy to trace the boundary of the cretaceous rocks by referring to the outline of the oolites. The chalk and its associated beds pass from Yorkshire through Lincolnshire, Norfolk, Suffolk, Hertfordshire, Bedfordshire, Buckinghamshire, Oxfordshire, Wiltshire, to Dorsetshire, always presenting a noble front of rounded hills to the west and north-west. Thence they return to the east through the isle of Purbeck and the Isle of Wight, offering a front to the south, while the broad inland surfaces, which are included between the Isle of Wight and the Hertfordshire Hills, are formed into two parallel synclinal troughs (the vales of London and of Hampshire), separated by one great anticlinal axis passing from Wiltshire to the coast of Kent, and continued into France in the district of Boulogne. The anticlinal axis alluded to changes through Sussex into a great denudation, or valley of elevation, exposing the Wealden formation in the centre, with escarpments of the cretaceous system on the north, south, and west in England, and on the east in France.

Hence, in general terms, we may say the chalk of England is distinctly related in escarpments and slopes to the present German Ocean and the eastern part of the English Channel. Were the level of the sea raised three hundred feet, its coast line would in all the eastern and south-eastern parts of England be parallel to escarpments of chalk.

The long range of chalk escarpment is too obvious a feature in the physical geography of England to have escaped notice; and in the infancy of geology we find Lister observing on its great extent and continuation with similar characters into France. It does not occur in Scotland, and

in Ireland is confined to the north-eastern portion, where it rests on greensand, lias, red sandstone, and coal-measures.

In France, the cretaceous system, commencing at Calais, opposite the Kentish margin of the great anticlinal denudation of the Weald, sweeps in a vast circle round Paris by Lille, Chalons, Troyes, Saumur, and Le Mans, to the embouchure of the Seine ; thus appearing as a great southward branch of the English chalk system, formed in a bay of the then ocean, which was defined between the mountains of Brittany, La Vendee, Auvergne, the French Jura, and the Ardennes.

From this great area (principally chalk) a broad expanded but mostly subterranean mass of cretaceous strata extends along the north side of the Ardennes and the valley of the Meuse, and continues (seen only at intervals at the surface) along the northern border of high ground in Germany, from Essen to Paderborn, turning as that border turns to Osnaburg, and then returning through Hanover and Brunswick. It reappears along the range of the Carpathians, and in some parts of the interior of the great tertiary plains which stretch to the north into Russia, and to the east to the Black Sea. In Denmark and Scania and along the Baltic (Isle of Rugen) chalk occurs in its usual character.

Along the northern and southern flanks of the Alps some beds of the cretaceous system range extensively, but not so clearly distinguished from the subjacent or superior strata as usual. Along the Pyrenees, however, the chalk system is very fully developed, and has been uplifted to great elevations by disturbances of comparatively recent date. In the south of Spain also chalk with flint occurs. In America rocks of the cretaceous period are abundant along the

eastern side of the United States, particularly in New Jersey, along the coasts of the Carolinas, in Georgia, Florida, and Alabama,[1] but true chalk is either wholly unknown or at least very rare.

Succession of Deposits.—In different parts of the geographical area above noticed, the cretaceous system differs considerably; yet, as in the case of the oolitic rocks, extreme differences from a common type are very limited, and evidently caused by local conditions, which insulated to a certain degree particular parts of the sea from the influence of the general agencies at work. If we take as a standard of comparison the complete English series, we shall find the following conspectus of its local variations useful.

Yorkshire.	Lincolnshire.	Cambridgeshire	Wiltshire.	South of England.
d. e. White chalk. Red chalk.	*d. e.* White chalk. Red chalk.	*e.* Flinty chalk	*e.* Soft chalk.	*e.* Flinty chalk.
		d. Hard chalk.	*d.* Hard chalk.	*d.* Hard chalk.
b. Clays, green and blue.	*a.* Green and irony sand, and calcareous beds.	*c.* Chalk marl.	*c.* Greensand.	*c.* Chalk marl and greensand.
		b. Golt.	*b.* Blue marl.	*b.* Golt.
		a. Ironsand.	*a.* Irony sand.	*a.* Lower green or iron-sand, and limestone.

Thus it appears that the most complete section is to be found in the south of England; the upper green sand losing itself very quickly to the north, the lower green or iron sand also vanishing north of Lincolnshire, and the golt and chalk constituting a binary instead of quinary system. The most constant of all the terms in this system in England are the upper portions of the chalk.

[1] Rogers in *Report of British Association for* 1834.

The section of this system in the north of Ireland (neighbourhood of Belfast) yields chalk, greensand, and golt. In the north of France generally the same five terms are found as in the south of England, though the golt is less distinct than in England, and the two sandy beds not so well defined. In the country north of the Ardennes and bordering on the Meuse, the chalky system, though less complete in the lower part (except about Aix la Chapelle), is much more developed in the upper part. In fact, a considerable mass of coarse, sandy, calcareous rocks, which is not really chalk, forming the hill of St Peter, near Maestricht, lies upon the ordinary cretaceous rocks of Belgium, and, both by its mineral and organic contents, offers a real though incomplete transition to the tertiary series of strata.

In the north of Germany both the chalky rocks above and the greensands below (Quadersandstein of Pirna, and other parts of Saxony adjoining the Erzgebirge) conform in many particulars to the English type. In the Carpathians the greensands predominate so as to constitute nearly the whole system. In the Alps, likewise, this is the case to a great extent, and it appears worthy of remark, 1st, that in the Salève and parts of the Jura there is a real alternation of greensands of the cretaceous type with the upper limestones of the oolite formation; 2d, that in particular parts of the north flanks of the Alps there appears to be a blending of the characters of the cretaceous and tertiary rocks (no chalk being found), so that it is hard to say where the line should be drawn.[1] This *transition*. as it is called, from the cretaceous to the tertiary strata is very different from that previously noticed at Maestricht,

[1] Murchison, Bouè, and others, on *the Gosau deposits*, *in Geol. Trans.* &c.

and seems to be due to an *insulation* of the Gosau and other districts, from the influence of the physical changes which elsewhere happened at the close of the secondary period, while the Maestricht transition may be viewed as one of the few monuments left to declare the nature of those changes.

In North America the most characteristic deposit, as along the Alps, is greensand, associated with limestones, compared to oolites in New Jersey, having a more chalky aspect in Florida and Alabama, where it assumes important features, but without real chalk or true flints. Some of the deposits in New Jersey resemble the lower green or iron sands of England.

It is thus rendered evident that the English type is more or less applicable to the greater portions of the earth's surface where the cretaceous system has been recognised; that the lower parts of the system are generally sandy, the upper parts often calcareous, but that the development of these two groups is not proportional nor depending on the same centres of influence. In the north of Europe the upper group seems generally to predominate, but in the middle of Europe the greensand system is more expanded and regular; in the northern parts of the United States the greensand abounds, in the southern calcareous rocks are more important. Yet upon the whole it must be granted that the agencies concerned in producing the cretaceous system were more extensive and uniform than those by which the oolites were accumulated.

Two formations are almost universally admitted as constituting the cretaceous system.

The Chalk Formation, named from the most characteristic mineral substance: thickness 600 feet. It includes

the following groups:—Maestricht beds, upper or flinty chalk, middle or hard chalk, lower chalk or chalk marl.

The Greensand Formation, commonly abounding in a green silicate of iron: thickness 600 feet. It includes upper greensand, &c. golt or blue marly clay, lower green or ironsand, with beds of sandy or chalky limestone.

Stratification.—In this system of strata, so evidently of watery origin, stratification, if Playfair's definition were adopted ("strata can only be formed by seams which are parallel throughout the entire mass") almost never occurs! In very many instances the chalk and greensand masses shew no more of stratification such as this definition requires than the primary rocks; but the cause is very different. Chalk differs remarkably in its composition and structure from most other calcareous deposits. It is generally an earthy, that is, feebly aggregated mass; it is seldom laminated like argillaceous limestones, unless where it is harder than usual, as for example on the Yorkshire coast and in some parts of the Isle of Wight. It contains evidence of consecutive deposition from a watery liquid as complete as any other rock. In general we find through a great mass of chalk a number of nodules of flint, variously shaped, but disposed in certain layers which are almost exactly parallel to one another, and to the bounding surface of the rock, and at equal distances, three to six feet. These serve to mark the successive deposits of the calcareous mass; and from the frequent occurrence of zoophytic remains in these nodules, especially in the south of England, it appears probable that the siliceous matter was separated from the calcareous, and collected round these bodies, by that molecular attraction which has been previously noticed in nodules of ironstone and spherules of oolite. We may

suppose, therefore, with Dr Buckland, an intermitting but abundant deposition of mingled carbonate of lime and silica, nearly equal quantities in each successive deposition, and that the silica was specially attracted to local centres by organic and other solidified masses. This of course applies only to the flinty chalk, which in the south of England is generally at the upper part, but in Yorkshire and at Havre flints are rather characteristic of the middle and lower parts of the mass.

The greensand formation shews the most complete stratification parallel to its bounding surfaces in those parts where the argillaceous golt and calcareous layers (*e. g.* in the vicinity of Folkstone and at the back of the Isle of Wight) vary the series of arenaceous aggregates. More regular stratification is nowhere to be seen than under such conditions. But where these divisions vanish, as in the western part of the great Wealden denudation (about Hazlemere, Leith Hill, Ryegate) the case is wholly different. The great mass of sand then exhibits little regularity of lamination, and besides is traversed by abundance of irony plates and shells in various directions, which render it nearly impossible to find any seams passing through the mass parallel to the bounding surfaces. In such a case, then, the nomenclature of Mr Smith coincides with the definition of Playfair, and several hundred feet of irregularly laminated sand constitute but one stratum.

Yet even in this extreme case the interrupted layers and nodules of chert (analogous to the flints in chalk) indicate the succession of deposits, and shew us that with respect to rocks of watery origin the adherence to the definition of stratification commonly received is likely to close the eyes of the observer on many more important matters.

The golt beds are generally laminated as other argillaceous deposits.

Organic remains occur in all the beds of the cretaceous system, and there is a considerable conformity in the lists which have been composed of the contents of the greensand and chalk formations. It is also observed that a considerable proportion of the organic remains which are found in a certain member of the system in England, also occurs in the same in France and Germany; that a small number of fossils may even be esteemed characteristic of the chalk, and others of the greensand formation. Locally, the several minor groups, and even particular layers, are distinguishable by their organic contents. But if we seek to apply this rule beyond the continent of Europe, nothing but disappointment ensues. In Egypt the chalky rocks contain different fossils from those which are known in England. Even the Scaglia of the southern faces of the Alps could not be identified by fossils with the chalk of England, much less could the greensand and chalky rocks of America, in the absence of other evidence, be referred to the cretaceous system by comparing the catalogue of *species* of organic remains.

What would be the feelings of a geologist accustomed to believe in the occurrence of particular *characteristic forms* at every step in the range of a certain rock, on finding in the cretaceous rocks of America, which contain 108 species of clearly defined organic remains, only two which are identical with those in the contemporaneous European rocks?[1] Yet in this we see only the illustration of a truth becoming every day more evident,—the measure of the influence of local physical differences; and instead of feel-

[1] Berger and Conybeare in *Geol. Trans.*

ing dismay at the loss of an (imaginary) infallible guide, we ought to be alive to the investigation of the *problem of contemporaneous difference* which this and other facts enunciate. There is still a remarkable *analogy* of the species buried on the two sides of the Atlantic during the cretaceous period. Exogyræ, gryphææ, baculites, belemnites, scaphites, ammonites, occur in America, as well as in the European greensand and chalky limestones; and it is possible that the specific differences of the organic forms may have been overrated, nothing being more difficult to define than the *natural limits of organic variation.*

In the following table, summaries of the invertebral organic remains of the cretaceous system mentioned by the authors of several works on the Geology of Sussex, Norfolk, Yorkshire, and Paris, are compared with a general catalogue of European fossils in this system, given by Mr De la Beche. In the Sussex and Norfolk catalogues, the numbers are in excess, because the same species has been counted in several beds of the system.[1]

	General Catalogue.	In the Geology of			
		Sussex.	Yorkshire.	Paris.	Norfolk.
Polyparia, . .	146	26	21	1	32
Radiaria, . .	85	29	16	10	34
Conch. Plagim.	87	32	13	4	
Mesom.	122	46	8	19	100
Rudista,	23	...	...	...	
Brach.	67	21	11	13	
Gasteropoda, .	56	31	8	4	40
Cephalopoda .	107	60	29	13	
Crustacea, .	11	13	3	...	1
Annulosa, . .	30	11	3	2	22
Cirripeda, . .	2	1	3	2	4

[1] See a Complete List of Greensand Fossils, by Dr Fitton, in *Geol. Trans.* 1836.

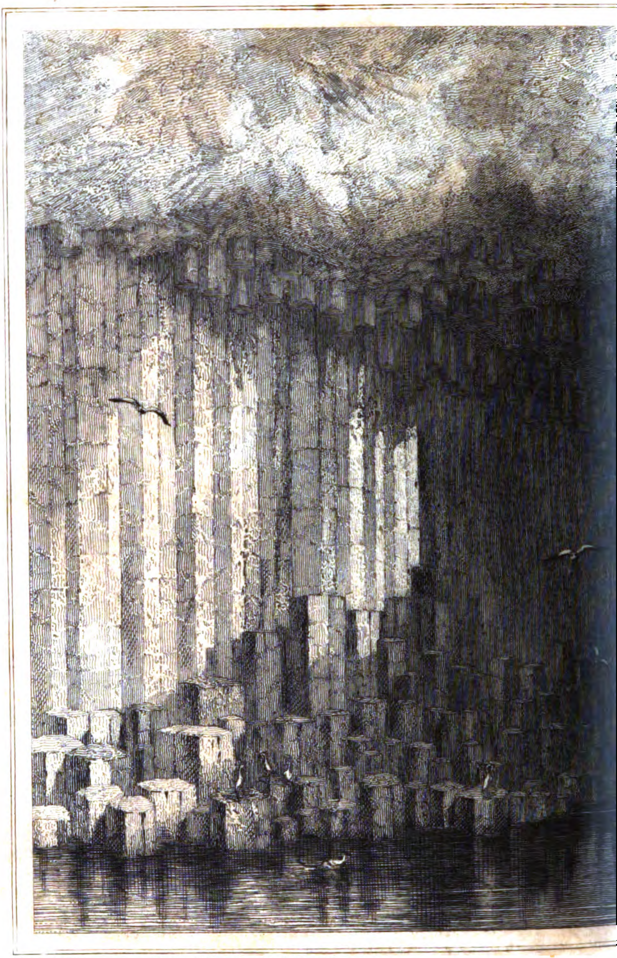
The distribution of the organic remains in the chalk and greensand formations, may be best illustrated from the geology of Sussex and the geology of Yorkshire.

	Chalk Formation.		Greensand Formation.	
	Sussex.	Yorkshire.	Sussex.	Yorkshire.
Zoophyta, generally, .	48	31	7	5
Conchifera, generally, .	57	10	46	22
Mollusca, generally, .	54	4	37	3

The small number of conchifera and mollusca in the Yorkshire chalk is remarkable.

Igneous Rocks.—In England, no rock of igneous origin is associated with the chalk or greensand. Such occurrences are less rare on the continent of Europe, among the Pyrenees and the Alps: at Weinhöhla, on the Danube, greensand is covered by sienitic rock. But the most remarkable occurrence is in the north-east of Ireland, where the chalk is almost universally covered by stratiform greenstone, basalt, and ochry rock, and traversed at several points by dykes of similar rocks, and in one place (Murloch Bay) entangled with a sienitic rock. A satisfactory notion of the nature of the mass of igneous rocks, which, in this part of Ireland, occupies nearly all the space to the east of a line from the south-eastern angle of Lough Neagh to the mouth of Lough Foyle, and in almost all parts rest on chalk and greensand, may be gathered from Dr Richardson's section of the cliffs near the Giant's Causeway.

Feet.
60 Basalt, rudely columnar.
9 Red ochre, or bole.
60 Basalt, irregularly prismatic.



Drawn with Camera Lucida, by Thos. Allan, Esqr. F.R.S.E.

FINGAL'S C

Engd. by G. Aikman, Edinr.

AVE, STAFFA.

Feet.	
7	Basalt, columnar.
8	Of a nature intermediate between bole and basalt.
10	Basalt, coarsely columnar.
54	Basalt, columnar, constituting the upper range of pillars at Bengore Head.
54	Basalt, irregularly prismatic. In this the wacke and wood-coal of Port Nocker.
44	Basalt, columnar, forming the Causeway.
22	Red bole, or ochre.
80	Tabular basalt, and thin seams of bole.
88	Do. occasionally containing zeolite.

The basaltic dykes which pass through the chalk in the island of Rathlin, and other places, convert it into granular crystallized limestone (close to the dyke *largely* crystallized), from which extreme change the effects diminish in proportion to the distance from the dyke, through the stages of small granular, arenaceous, and compact stone, to the ordinary chalk. (The Irish chalk is more close-grained than the English.) The colour of the chalk is altered also; near the dyke very brown, at a certain distance bluish, further off yellowish.[1] It is not improbable that much of the basaltic formation of the western coasts of Scotland, including the magnificent pillared rocks of Staffa (see the very correct engravings annexed), are of the same date as the Causeway rocks.

Disturbance.—Throughout England there is little or no proof of any considerable disturbing movements following upon the deposition of the chalk; yet, from the character of the lower tertiary strata of England which rest upon the chalk, it appears undoubted that considerable agitation of water occurred, for the surface of the chalk was wasted,

[1] Rogers in *Report to the British Association.*

and conglomerate or pebble beds formed of the detrital flints. The mass of igneous rocks poured out on the chalk of Ireland, is of too indefinite an age to be appealed to as proof of convulsions in that quarter. But on the continent of Europe, De Beaumont assigns to this period his Pyreneo-apennine system of convulsion,—the elevation of the Pyrenees, Carpathians, Northern Apennines, Dalmatia, and the Morea, in lines ranging parallel to a great circle on the sphere through Natchez and the Persian Gulf. It appears also that some disturbances which happened *during* the cretaceous era, are traceable in Mont Viso and the Western Alps. Supposing the Pyreneo-apennine system to be principally, if not wholly referrible to this period, we seem to behold a reason for the agitation of the shores of the English chalk basin; the distant convulsion might sufficiently explain this local and transient agitation, but, in fact, it is very probable that the English chalk underwent a gradual local elevation, which contracted the area of the bordering seas, and formed shores and dry land slopes of chalk, to be wasted by the waves, the rivers, and the rains. The pebble-beds of the tertiaries which rest on the chalk of England, do indeed more exactly correspond to such an origin than to the effect of sudden and violent disturbance.

TERTIARY STRATA.

Base of the Strata.—We have seen that during the long and yet unmeasured period which elapsed during the accumulation of the secondary strata, elevation of the land continually happened by gradual forces, and sometimes by violent disturbance. The most striking case of the latter

is the general disruption of the coal system, at least before the completion of the red sandstone deposition. Of the gradual elevation of strata, almost the whole series furnishes continual proof. Hence it is, that the oolitic rocks follow one another so exactly in their geographical boundaries, retiring continually into smaller and narrower areas, as the elevation of the old land proceeded. In the continuation of the process, the greensand and chalk form, at least in England and France, a still interior band of deposits, which mark the gradual contraction of the seas, that is, the gradual uprising of the land.

The tertiary strata have, in general, to the chalk the same geographical relations as that to the oolites. Throughout England, the chalk is the base of all the tertiary strata. In France this is generally the case, and almost universally so for the marine tertiaries. In the north of Germany, along the north and south slopes of the Alps, and in the basin of the Danube, this is at least very extensively true. In North America, the general basis of the tertiaries is the cretaceous formation. On more close inquiry, it appears, however, that the tertiary strata are seldom exactly conformed to the stratification of the chalk; that any thing like a gradation or alternation of the cretaceous into tertiary deposits, is rarely known; that the organic remains of the one group differ almost wholly and absolutely, except in the south of France, at Maestricht, &c., and constitute two distinct groups of created life. Hence it has become a popular opinion, that with the secondary strata ended a certain general condition of the globe, and with the tertiaries commenced a totally new arrangement. Moreover, because we find the marine tertiary strata distinctly related, in geographical expansion, to the present basins and arms of the

ocean; as the organic remains which they contain are similar, and, in rocks of later date, identical to those of the existing races in the sea and on the land; and as the tertiary sediments are of a nature very analogous to the daily products of the sea, estuaries, tide-rivers, and lakes,—there is but a step farther to unite the tertiary era with the historical period of the globe, and to place the commencement of the actual creation or arrangement of organic nature at the epoch immediately following the chalk. For these and other reasons, the tertiary strata are of great interest. They admit of a clear comparison, in all respects, with the effects which daily occur before our eyes; and thus facilitate our inquiry into the conditions of nature in earlier periods. They furnish the principal arguments on which Mr Lyell rests his doctrines of the continual uniformity of the measure of terrestrial agencies, as the older strata have long done to those who maintain that, in the construction of the crust of the globe, periods of ordinary action have been broken by crises of unusual violence.

Nature of the Tertiary Strata.—In very few instances, during our survey of the products of earlier nature, have we found reason to admit the deposition of strata in any other waters than those of the sea, in its depths and along its shores. The coal deposits of the north of England generally belong to the class of estuary formations, in which the influence of the sea was often less and never more sensible than in the bed of a tide-river, where the water is only brackish. At intervals, indeed (Yorkshire coal-field), when great distant disturbance or local change of the circumstances occurred, the influence of the sea has returned and produced its usual effects, leaving, as monuments of its short dominion, peculiar kinds of animal exuviæ.

The oolitic formation on the Yorkshire coast and in Sutherland proves plainly enough the local addition of fresh waters and spoils from the land; the Wealden formation indicates, in like manner, a wide estuary fed by some river, on whose banks gigantic reptiles or tropical plants abounded; but nothing has yet been shewn with respect to any carboniferous or oolitic deposit, which renders necessary the supposition *of lacustrine or purely fresh-water deposits.* Communication with the sea from the basins of the coal deposits, and from the Wealden beds, is apparently indispensable in explaining the occurrence of particular sorts of fishes in these strata, and not in any respect inconsistent with the evidence of the molluscous exuviæ. The most plausible arguments for fresh-water deposits among the older strata, are advanced by Dr Hibbert in his description of the Burdiehouse fossils, and by Mr Murchison in his notices of Shropshire coal-fields. Without in the least wishing to intimate that the influence of fresh-water in accumulating the materials of the strata is most conspicuous in the newer strata,—an inference not justifiable by the facts,—it is to be remarked, that the deposition of stratified rocks in limited basins of fresh-water is a phenomenon almost characteristic of the tertiary period.

The same tracts of watery surface beneath which the coal-field of Yorkshire was formed suffered alternate influence of the sea and river water. The estuary of the Wealden, and the coal deposit of the oolitic hills, were alike formed upon the bed of formerly deep seas, and at a later period deep sea again covered the same area: in a certain sense, the deposits of fresh and salt water alternate in several secondary formations. But in the tertiary strata, this phenomenon of alternating marine and fresh-water products is more decided

and remarkable. In the basin of Paris, at least two fresh-water and two marine deposits alternate in the tertiary series. Alternations of really fresh-water and really marine products happen in the south of France, the valley of the Rhine, in Hungary, and the Isle of Wight. In these cases the explanation is possible, without supposing repeated upliftings and submersions of the land—of which, from other phenomena, there is no evidence—by merely conceiving estuaries or expansions of water, such that the influence of rivers and the sea might alternately predominate, just as, in fact, we know to have happened, even in historical times, in the marshes of East Norfolk,—and as must have often occurred in similar tracts at the mouths of rivers where variable sand-banks abound, and alter the direction of littoral currents. At some later epoch, the whole bed of the estuary has been uplifted to its present elevation above the sea.

Nature of the Marine and Fresh-water Deposits.—It is a remarkable confirmation of the views of modern geologists, that a great portion of the substance of sedimentary strata was swept down to the sea by inundations and other watery forces operating on the surface of the dry land,—that the marine and fresh-water sediments of the tertiary era have so much general analogy. In each we have calcareous, argillaceous, and arenaceous deposits, alternating,—stratified, laminated, in a similar manner; the organic exuviæ are similarly disposed in the beds, and, but from the character of these, we could not in general venture to pronounce upon the nature of the water in which the beds were deposited. Some distinction is, however, to be traced; the marine arenaceous sediments are thicker and more confused than those of fresh-water; the marine clays are less minutely laminated. It may be remarked, in general, that

limestones and fine light-coloured clays constitute the principal mass of the fresh-water sediments; while sands, and blue and variously-coloured clays more particularly mark the marine depositions. The latter appear like the products of littoral agitation, as if the wearing of cliffs of older strata had furnished the materials of these newer rocks; while the former resemble the accumulations from the wasting surface of chalky and argillaceous countries. This is more particularly the case in the Isle of Wight, where the coloured sands of the marine tertiaries might seem really to have drifted only a few miles from the equally-coloured sands of the greensand and Wealden formations; while the fresh-water marls and limestone may be imagined to have been added from a wasting surface of chalk hills.

SCALE OF GEOLOGICAL TIME.

In all our former inquiries, the successive geological periods have been arranged by the marine deposits and marine fossils; and the same plan must be followed in these tertiary rocks if we wish to preserve consistency. The true plan of comparing the tertiary and earlier strata, in reference to chronology, is to reject the lacustrine and estuary deposits, and the remains of land and fresh-water animals and plants, and confine ourselves to the marine productions merely. Had this prudence been duly observed in geological reasoning, much inconsistency and contradiction might have been avoided; the fresh-water depositions (which are merely local terms in the series of strata), would not have been appealed to in proof of the relative ages of marine deposits, nor should we have been led, by the occurrence of a few exuviæ of land mammalia, into conclusions at variance with the evidence of marine invertebrata, which are the true indices of past geological time.

Succession of time, as determined by marine productions, is the true scale of geological classification; and it is clear that the fresh-water strata of any series can only be determined in age by their relations to the marine; also, as the laws of changes of organic life, which are gradually unfolded by geology, are founded, in the first instance at least, on the facts known with reference to marine fossils, it is to this standard that the independent series of analogous changes on the land must be referred. The *rate* of such changes on the land, however real and regular, may have been wholly different from that in the sea, and must be studied apart. This reasoning leads directly to a classification of the phenomena of tertiary deposits under three heads,—

The Marine deposits,
The Fluviatile deposits, alternating with marine deposits,
The Lacustrine deposits;

a classification, however, which is better suited to a philosophical review of the results of investigation than to a description of the phenomena, for these are often intimately associated.

BRITISH MARINE TERTIARY DEPOSITS.

Geographical Extent.—In Europe, the area covered by marine tertiaries is scarcely inferior in extent to that occupied by either the primary or secondary series. Ireland and Scotland, and all their dependent islands, are wholly deficient in these strata, unless we choose to make exceptions in favour of uplifted beaches whose date is yet uncertain, like the terraces on the sides of the Forth, and the shelly beds on the coast of Wexford. No tertiaries occur in Wales, unless the shelly gravel on the north face of Snowdonia be of this date; neither do any traces of these deposits occur

on the coast of England further north than Bridlington in Yorkshire, nor to the west of the Isle of Purbeck. Raised beaches, however, are met with beyond these boundaries. Inland, the tertiaries follow a line parallel to the chalk escarpment in all its great flexures, and along the east and west axes of dislocation. There are, consequently, two great troughs or basins of tertiary strata, viz. those of London and Hampshire, both ranging east and west.

Succession of Strata.—It is remarkable that in these two basins principally, though not exclusively, lie the lower members of the tertiary series of England, while other members have mostly a local distribution, depending on different circumstances. No complete type of the English series can be had at any one locality, not even in the Isle of Wight, where alone the fresh-water formations are distinctly seen. To compose a complete section, we must add together the strata of Norfolk and Suffolk, the beds of the London basin, and the varied deposits of the Isle of Wight. We thus find that the marine deposits of England range themselves in three groups, viz.

Upper group or Crag,...............Generally arenaceous.
Middle group or London Clay, ...Mostly argillaceous.
Lower group, or plastic clay, &c...Clays and sands.

Of these the upper group occurs only in Norfolk, Suffolk, and Essex (unless the tertiaries of Bridlington may be classed with it); the lower group is confined to the basins of London and Hampshire. The following is a sketch of the state of knowledge concerning each of these groups.

The Lower Group of Plastic Clays and Sands is best seen in the Isle of Wight, where its characters are easily examined at Alum Bay, at the west end of the island. Mr

Webster, who first described this interesting spot, gives the following succession of the beds lying next to chalk, all vertical or nearly so. The chalk is covered by a calcareous marly bed, probably not related to the tertiary deposit. Then follow 60 feet of green, red, and yellow sand; 200 feet of dark blue clay, with greensand and septaria, and a few shells; 321 feet of variously-coloured sands; 543 feet of pipe-clays and sands of various colours, which, by crumbling and exposing fresh faces, shew very bright and splendid tints of white, yellow, orange, red, green, grey, and black. Near the middle, lignite is found in these beds (with remains of fruit); and in the higher part toward the north, five other beds of lignite occur, each about a foot thick; rolled black flints in yellow sand. (Dark coloured clay 250 feet thick, with greensand and septaria, and abundance of shells of the London clay closes the series.) Reduced in thickness, these sandy and argillaceous layers continue both east and west. At Poole they yield valuable pipe-clay and sands.

In the basin of London the plastic clays and sands vary in thickness and quality, but present general analogies with those of the Isle of Wight, in the variously-coloured sands and clays of Reading, layers of worn flint pebbles (Blackheath), mostly very small, and a few beds of shelly clay (Woolwich.) It is in most places somewhat confused in lamination, full of indications of littoral agitation, and apparently accumulated with considerable rapidity by very limited agencies. Whence have come the masses of sandy materials which compose this deposit in the two basins in question? We have already said that in the Isle of Wight it appeared as if the tertiary sands had been derived from the ruins of the very similar subcretaceous rocks of the vicinity. Perhaps the hypothesis may be extended to the

basin of London, (once certainly united with that of Hampshire.) Mr Lyell, indeed, in reasoning on the basin of London, has proposed the ingenious hypothesis of the accumulation of all the materials of these basins from the waste of the Wealden district, assumed to be then rising gradually to encounter the ravages of the atmosphere. The evidence is not satisfactory, and the supposition involves a point of some importance not yet conceded, viz. the gradual elevation of the Wealden district. At all events, the probability is great that some uplifted greensand ranges contributed materials to the plastic clay formation.

The Middle Group, or *London Clay*, is most fully developed in the vale of the Thames, and best known in the vicinity of London. The numerous wells established here have shewn the inferiority of the plastic clays and sands to the London clay, and contributed to make known the characters of this great argillaceous deposit, which, in some places, is above 500 or 600 feet thick, and in Essex, at High Beach, 700 feet, according to Conybeare and Phillips.

In this great thickness of blue and brown clay is little variety, except what is caused by a few layers of nodular septaria, and toward the bottom greensands or sandstones, (which are more fully developed at Bognor on the coast of Sussex.) Laminated shelly beds also occur (Knightsbridge Well), and in the Harwich Cliff are layers of stratified limestone, (Greenough, in *Geol. of Engl. and Wales*, p. 24.)

Organic remains are nowhere rare in this deposit, and, in particular localities, extremely abundant; 239 species are mentioned by M. Deshayes from the London clay, principally of Hampshire and Highgate; and of these only twelve, or five per cent., have been found living in the present seas.

What is the origin of this mass of clay? Mr Lyell supposes the uplifted Weald of Kent and Sussex to have yielded the materials of the whole of the marine tertiaries to the north and south; that waste of the sandy tracts of the Weald furnished the plastic clays and sands, and the Weald clays contributed the argillaceous sediments. But this speculation can neither be advocated nor opposed except by trains of argument involving too many assumptions to be satisfactorily admissible in inductive geology.

The Upper Group, or Crag Formation, is a local deposit of a character very different from all the older strata. It consists of two parts, which, according to recent researches of Mr Charlesworth, are placed in superposition at some points on the eastern coast, particularly Ramsholt near Woodbridge. The lower part is either a loose, partially calcareous sandy mass (Ramsholt), very full of shells, and containing a considerable quantity of corals, not at all agreeing with the zoophyta of the German Ocean, or else a coarse sandy zoophytic limestone (Aldborough and Orford), in which some of the same shells occur. The thickness of the lower, or coralline crag, is not certainly known; from seven to twelve feet are exposed; it is scarcely ferruginous; shews no considerable marks of watery agitation; pebbles and rolled shells are not seen in it.

In these particulars it differs much from the upper or red crag, which shews, by its very confused, often curved, and obliquely-intersecting lamination, by its abundance of rolled pebbles, bones, and shells, proofs of having been accumulated under the influence of agitated waters. No trace of land plants occurs; in general no alternation of clay deposits is seen; and though a few bones of mammalia have been found (as in the older and quietly deposited

tertiaries of Italy), there can be no doubt that the whole is a littoral marine accumulation. The whole is very ferruginous. Shells are excessively plentiful; and in fact constitute, in some places near Woodbridge, the principal part of the mass. Corals are very rare (though not absolutely unknown); and solenostomatous gasteropoda, (including reversed whelks), very plentiful.

From the composition and character of the upper or red crag we may venture to adopt the opinion, that it is little else than an elevated beach of the German Ocean, parallel to the shore of which it is extended from north to south through the eastern parts of Norfolk and Suffolk. The coralline crag below it may be viewed as a less disturbed product of the same ocean farther toward the deep sea.

What relation does this shelly deposit bear to the actual beach and littoral bed of the German Ocean? This question brings us to a more close consideration of the organic remains of the crag, which, according to Mr Charlesworth, amount, in the collection of Mr Wood of Hasketon near Woodbridge, to 470 species, viz.—

Annulosa, ...	13	Conchifera, . . .	189
Cirripeda, ...	11	Mollusca, . . .	257

Of these 111 have been examined by Deshayes, and he assigns 45 of these (40.1 per cent.) to recent types mostly found in European seas. In the coralline crag Mr Charlesworth finds 350 species of testacea, and in the red crag 230; 150 are common to both the deposits; 80 are peculiar to the red crag; 200 to the coralline crag.

M. Deshayes' result, quoted above, was principally founded on an examination of the red crag. Lately he has also examined a portion of the shells of the coralline crag, and finds in these the same, or rather greater, proportion of re-

cent species.[1] According to this evidence, the lower or coralline crag is to be classed with the red crag; as a somewhat anterior deposit, produced under different local conditions, but including organic exuviæ which bear the same numerical relations to the present forms of marine invertebrata. In some of the Norfolk crag are *detrital fossils* from the chalk and oolitic series of rocks.

A deposit of shelly sands and clays has recently been found on the coast of Yorkshire at Bridlington Quay, which cannot at present be referred to its true place in the scale of British marine tertiaries.

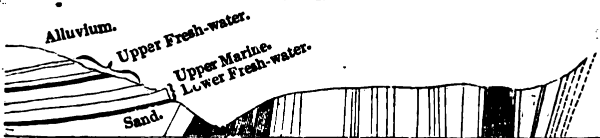
The green and yellow sands and blue clays, which contain the shells, form the base of a perishing diluvial cliff; and, in the compass of a few yards' length, fifty-five species of shells have been found, besides some small cephalopoda, and several bones and teeth of fishes. Of the shells, four species are also found in the crag—five or six are identical with living species—a considerable part of the remainder are, as far as yet known, peculiar to this locality.[2]

BRITISH FRESH-WATER DEPOSITS.

These are confined to the Isle of Wight and part of the adjacent coast of Hampshire. Mr Webster first called public attention to them. Against the London clay mentioned in the section of Alum Bay rest a considerable mass of sands, chiefly white or light coloured, which gradually lose the verticality of the dislocated beds here, and turn so as to become almost perfectly horizontal. (See Diag. No. 14.) Upon these lies a mass of nearly level stratified marls and limestones constituting Headen Hill. These calcareous marls, &c. constitute the fresh-water formation, and they are

[1] Proceedings of British Association at Dublin. [2] Ibid.

No. 14.



parted into two groups, upper and lower fresh-water beds, by an intermediate set of strata containing estuary and some really marine shells.

The Upper Fresh-water Group consists of thick limestone and marl beds, full of limneæ, planorbes, and other fresh-water shells; the limestone is partly compact and partly loose and *chalky;* the marls of a light greenish-yellow or blue; altogether fifty feet or more thick.

The Middle or Estuary Group is about thirty-six feet thick in Headen Hill; it is a greenish marl, *not materially different* from some of the fresh-water beds, and is actually crammed full of neritina, potamida, ancillaria, and many other small estuary and marine shells. A bed of oysters occurs with them in another part of the island.

The Lower Fresh-water Group, sixty-three feet thick in Headen Hill, is very like the upper beds (at Binstead are alternations of siliceous limestone); the lower part is a dark clay. Fresh-water shells are very numerous in particular layers. Below is white sand without fossils.

FOREIGN TERTIARY STRATA.

Though the English tertiary strata occupy but a very small space, compared to the wide extent of these strata on the continent, they are not inferior in interest to those of any district in Europe. There is a very remarkable analogy between the tertiaries of the basin of Paris and

those of the basin of Hampshire, extending even to the number and circumstances of the fresh-water beds, accompanied, however, by as remarkable a difference in the composition and character of one part of the series. The following is the arrangement of the tertiary strata near Paris adopted by Cuvier and Brongniart, (Tableaux des Terrains).

Upper Fresh-water or Epilimnic Group, consists of two sorts of rocks, separate or in combination, viz. marly limestones with calcareous or argillaceous marls, and siliceous rocks. The former always shew tubular cavities proceeding upwards, *as if gas had passed through the sediment* while soft. The latter consist principally of the cavernous siliceous substance called French burr, in some portions of which are shells.

Upper Marine Group, consisting of sands and sandstones of various colours, and some conglomerates with a few shells and marly beds.

Lower Fresh-water, or Palæotherian Group, consisting of siliceous limestone, marls, clays, and gypsum, with a considerable number of lacustrine shells and bones of extinct pachydermata, and a few land and fresh-water plants.

Lower Marine Formation, or Calcaire grossier ; a thick bedded coarse-grained shelly limestone, with abundance of marine zoophyta, shells, and fishes, some cetacea, &c. Some sandy beds accompany it, and grains of green silicate of iron.

Plastic Clays and Sands of different colours, as green, reddish; beds of lignite in the upper part; some limited layers of detrital pebbles in the lower part; few organic remains.

It will be seen from this brief notice of the tertiaries of the basin of Paris, that they present a marked general

agreement with those of Hampshire; similar plastic clays and sands below; similar alternations of fresh-water and marine strata above. Yet the particular differences are even more striking. If the general agreements indicate some predominant analogies of physical conditions, spreading each way from the English channel, these particular differences are no less instructive in shewing the essential diversity of phenomena arising from local circumstances. The lower marine formation of the Paris basin corresponds in geological age with the London clay, and contains the same organic fossils, with many others; but it is a calcareous, and not argillaceous, deposit. The fresh-water formations differ considerably from those of the Isle of Wight, by the prevalence of siliceous concretions and beds, the local production of gypsum and other circumstances.

It appears by no means unlikely that the lower fresh-water beds of the Paris basin are really the equivalent of both the fresh-water deposits of the Isle of Wight, while the upper Parisian deposit from fresh water has more the air of a really lacustrine accumulation, and is the most recent deposit in the district.

The tertiary series in the south of France has a general analogy to that of the vicinity of Paris; but the differences are great, and, upon the whole, tend to produce a correspondence with that of Italy. The following is the arrangement of beds:—

Upper Fresh-water Lacustrine deposit, containing shells, insects, and plants.

Upper marine beds.

Sands. Micaceous and light-coloured, with remains of land and marine mammalia, land and fresh-water reptiles, fishes and shells.

Marls and limestone, (*calcaire moellon*), with remains of marine mammalia, fishes, mollusca, principally in the upper beds.

Argillaceous marls, the same as the blue subapennine marls, with marine shells in abundance; terrestrial exuviæ rare; an estuary bed enclosed.

Lower Fresh-water Formation. Pisolitic limestone; marly and siliceous limestones, with land and river shells; marls, silex, and slaty magnesite with gypsum, containing land and fresh-water exuviæ.

Lower Marine Formation. Calcaire grossier; greensands, &c.; inferior clays, lignites, &c.

Combining the sections of the subapennine and Sicilian formations, but rejecting the superficial gravel and detritus, we have three principal terms:

Upper Subapennine, or Sicilian deposits. In the Val di Noto is the most complete section of these comparatively recent beds. The uppermost group, which rises in Castrogiovanni to 3000 feet above the sea, is calcareous, sometimes 700 or 800 feet thick, stratified, and locally solid. The organic remains are almost exclusively of recent marine species. The middle group is a white calcareous sand or yellow sand, like what is found covering the sub-apennine marls in Italy. The lowest group is a blue argillaceous marl, with numerous fossils, mostly of recent species (Dr Daubeny and Mr Lyell).

Middle Subapennine deposits. Several thousand feet thick, composed of fine laminated, argillaceous, and calcareous marls, and blue clays; with rare interpolations of lignite, sandstone, and thin limestone; abundance of organic remains, often referrible to

existing marine testacea, &c., and a few instances of imbedded remains of land mammalia (Mr Lyell).

Lower Subapennines. These occur in the Superga, near Turin, and consist of greensand sand marls, resting on a conglomerate of fragments of primary rocks (Brongniart, Lyell).

The researches of Murchison and Sedgwick on the north flanks of the Austrian Alps, those of Boué in Transylvania, and of Studer in Switzerland, have yielded complete information as to the tertiary strata of these districts. The most complete section is that given by the English geologists in Lower Styria.

Uppermost group. Calcareous sand and pebble beds, calcareous grits and oolitic limestone; shells are plentiful; some of them still exist in the sea. White and blue marl, calcareous grit, white marlstone; and concretionary white limestone, containing shells.

Middle group. Coralline limestone and marls, several hundred feet thick; organic remains of the *middle subapennines*.

Lower group. Conglomerate, with micaceo-calcareous sand and millstone; dark blue marly shale, sand, &c. Some of the shells are identical with species of the calcaire grossier and London clay; shale and sandstone with lignitic coal, containing bones of anthracotheria and fluviatile shells and plants, micaceous sandstones, grits and conglomerates of primary detritus.

Without adding to these details the sections along the Carpathians, and in the plains which extend from them to the north, we may proceed to offer a short view of the general analogies and distinctions which appear to prevail

among the tertiary strata of Europe with reference to *geological time*.

Mineral Composition.—It is evident, from comparing the sections given, that no special resemblance of the strata in thickness or mineral composition can be traced, such as we have found to be frequently observable while examining the older strata. All are composed principally of calcareous, arenaceous, and argillaceous matter; but so are all the secondary strata. We do not find in the different regions compared any settled order of succession among the rocks of different nature. The English series has no marine limestone; the Parisian no thick marine clays; the subapennine deposits have little arenaceous matter. It is apparent, in fact, that the tertiary deposits vary as to their mineral composition very much more in relation to locality than to geological time,—a fact which at once subverts all hope of arranging them in geological chronology by comparison of their mineral constitution. It also leads us to infer that the deposition of tertiary strata took place in arms and gulfs of the sea, which ramified among the masses of land then raised in Europe, and derived sediments of different nature from these different lands. Hence the subalpine tertiaries have one character; those of the subapennines another; the subpyrenean a third; the Parisian a fourth; the English a fifth.

By prosecuting this research, we find, in fact, that the tertiary formation was sometimes produced in insulated seas, like the Adriatic, and the valleys of the Rhine and Danube; at other times under the influence of the general ocean, as those in the plains of the Garonne; often in basins, like the Parisian series. Thus a principle of classification is indicated, not entirely inapplicable, it is true, to

the older strata, because these were also dependent on local conditions, but yet in a peculiar sense appropriate to this comparatively modern system of deposits.

It is easy, in fact, to perceive, that, by the united effect of so many systems of disturbing movements, the expanded seas, in which the older strata were deposited, had been either divided into portions completely separate, or united by narrow straits, or placed under very different relations to oceanic currents and inundations from the land. In consequence, the causes of local diversity, always operating from the very commencement of geological time, approached their maximum of effect in the tertiary periods, and left among contemporaneous marine deposits very slight analogies.

Organic Remains.—But the phenomena of organic life offer us another and independent scale of comparison, which the principles of Smith, developed by the researches of Deshayes, and the reasoning of Lyell, have encouraged us to apply to the tertiary strata, for the purpose of determining *in each district*, those lines of contemporaneity, without which geological history has no principle of combination,—no clew to general laws.

For the sake of precision in our inquiries, let us suppose, in conformity with the general bearing of all the results arrived at by investigations among the earlier strata, that the *changes of marine organic life* were, in the region of Europe, during all the tertiary periods, *proportional to the time elapsed;* and since the tertiary strata contain forms identical with living species, let us agree to form our scale of geological time, as indicated by the change of organic life, by reference to the present catalogues of invertebral animals living in the sea and fresh-waters.

According to the proportionate number (or per-centage) of fossil forms identical with living species which are found in any tertiary stratum, its date will be nearer to or further from the epoch of the commencement of the present order and arrangement of living nature. That this principle is strictly and generally true, can neither be proved nor granted; because it is neither proved nor probable that the influential circumstances according to which the changes of organic life proceeded, varied in any place, much less in all places, exactly in proportion to the time elapsed. Yet the change of organic forms is probably the most general and strict measure of time *which can be found* among the tertiary strata; and in adopting it Mr Lyell has certainly entered upon a very interesting train of inquiry, capable perhaps of even more exact application among the strata of older date, when the contemporaneous conditions of different parts of the globe were certainly more uniform than during any part of the tertiary period.

It is indeed this very diversity of local conditions that makes it extremely doubtful how far we may venture to apply to individual cases the law which perhaps may be true only of the assemblage; just as a mathematical expression for terrestrial temperature of the surface may be quite exact for the mean of a whole zone of latitude, yet not correct in any one point of the whole surface, because of different circumstances.

For example, the shores of Italy are margined by tertiary deposits, which have been raised out of the existing Mediterranean Sea, and contain many species of marine exuviæ still living in that sea, and nowhere else. The vale of the Danube is also full of tertiaries, which contain many shells; but this once tertiary sea has been *wholly laid dry*,

and all its *peculiar* testacea are imbedded in the earth. It is apparent that the fossils of Italian tertiaries will shew numerically greater resemblance to existing species, than those which lie in the contemporaneous deposits of the Danube, the numerical difference being in proportion to the (unknown) number of shells which in a former condition of the globe *were peculiar to that now dried tertiary sea.*

Some difficulties connected with the application of the principle to the comparison of different basins, no time can remove; others will be diminished by further research; and in almost every instance important results will arise from exact researches to test its truth in every separate basin or branch of the old tertiary sea.

We may now proceed to shew the results of the inquiry conducted by M. Deshayes, upon the supposition of the relative antiquity of tertiary beds being inversely proportioned to the per-centage of recent species among its imbedded fossils.[1]

Commencing with the English tertiaries, we find from M. Deshayes, that among 111 species of shells from the Crag, 45 are living; = 40.1 per cent.; and of 239 from London clay, 12 are living; = 5 per cent.

Proceeding to the basin of Paris, it appears that among 1122 species of shells, 38 are still living; = 3.4 per cent.

On the Atlantic shore of France—1. At Angers, out of 166 species, 25 are still living; = 15.0 per cent. 2. In Touraine, out of 298 species, 68 are still living = 22.7 per cent. 3. In the vicinity of Bordeaux and Dax, out of 594 species, 136 are still living; = 22.9 per cent.

The subapennine series of Italy and Sicily—1. Lower

[1] Lyell's *Principles of Geology*, vol. iii. (1st Edition).

subapennine (Turin), out of 97 species, 17 are still living; =17.5 per cent. 2. Middle subapennines, out of 569 species, 238 are still living; = 41.8 per cent. 3. Upper (or Sicilian beds), out of 226 species, 216 are still living; = 95.1 per cent.

The tertiaries of the Danube and Rhine—Baden, out of 99 species, 26 are still living; = 26.2 per cent. Vienna (and north of Carpathians), out of 124 species, 35 are still living; = 28.2 per cent.

From these and some other investigations, M. Deshayes was led to group the tertiary deposits in three assemblages, viz.—The most ancient, including the Parisian and London and Hampshire beds; those of Valognes, near Cherbourg, and Belgium; Ronca and Castel Gomberto. From this series 1238 species of shells have been examined by M. Deshayes, who finds 42 of them, or 3.5 per cent. still living. To these Mr Lyell gives the name of Eocene deposites (ἠως, the dawn; καινος, recent.)

The middle assemblage includes the beds of Bordeaux, Dax, Touraine, Angers, Baden, Vienna, Hungary, Transylvania, Moravia, and the country north of the Carpathians. Ronca is also provisionally included by M. Deshayes, but, as he conjectures, it would be more properly transferred to the older division: 1155 species of shells are mentioned, of which 176 are still living, being 15.2 per cent. These are called Meiocene by Mr Lyell (μειων, less; καινος).

The upper assemblage contains the fossils of Italy, Sicily, Perpignan, the Morea, and the English Crag, 770 species, of which 350 are recent, or 45.4 per cent. To these Mr Lyell gives the name of Pleiocene (πλειων, more, and καινος); but he distinguishes them into two divisions—older pleiocene,

including the English crag and middle subapennines of Italy; and newer pleiocene, composed solely of the Sicilian deposits.

Mr Rogers has lately applied to the tertiaries of North America the results of Deshayes and the nomenclature of Lyell. The species are generally different on the two sides of the Atlantic, both among the tertiary fossils and living shells. The oldest American tertiaries are more analogous in their fossil contents to the secondary rocks than is found to be the case in Europe; they contain 210 species, of which hardly one is recent. The middle tertiary formations (supposed to include meiocene and older pleiocene), contain 195 species, of which 40, or 21 per cent., are recent; the most recent (newer pleiocene) are very limited in extent.

Fresh-water Organic Remains of the Tertiary Era.—In the preceding account of M. Deshayes' tables and Mr Lyell's nomenclature, we have retained the numerical statements of these authors, though liable to one slight objection, the introduction of the remains of fresh-water and land mollusca. These amount to 259 species, a number too small to influence materially the resulting classification. There are of fresh-water bivalves in the fossil state, 30 species; of univalves, 151 species; and of land shells (univalves), 78;—in all 259.

Though the far greater part of these belong to species no longer in existence, all are included in the same genera, and there is no particular reason to be gathered from them for admitting that the climate or local conditions of the land of Europe during the tertiary era was very different from what is now experienced.

Any one who knows the variation of the forms of existing Limneæ and Unionidæ in fresh waters of different na-

ture and degrees of agitation, may be forgiven if he does not at once perceive and acknowledge the minute distinctions which really exist between the tertiary and existing fresh-water shells. A small number of fresh-water plants (Characeæ, Equisetaceæ), occurs in the calcareous deposits of the basin of Paris, and great masses of lignite, derived from land plants in the sands and sandstones of Switzerland, France, and England, and they all shew great analogy to existing plants.

Terrestrial Organic Remains of the Tertiary Era. These consist of a few land plants and mollusca, with a considerable number of the remains of mammalia. In the fresh-water deposits of Hampshire, Paris, &c. belonging to the eocene period, the bones of certain extinct races of quadrupeds occur, as the palæotherium, anoplotherium, lophiodon, dichobune, &c.; with living genera, as vespertilio, canis, sciurus. In the lignite beds of Styria and Switzerland, anthracotheria, beavers, &c. abound; in the superficial lacustrine beds of central France, Oeningen, &c. the bones of rhinoceros, felis, ursus, fox, and other modern genera are imbedded. In some cases, as at Georgesgmünd, the bones of extinct genera (palæotherium, anoplotherium, mastodon); and existing genera, as hippopotamus, horse, ox, mustela, fox, are found together, but this is not generally the case.

Several instances are known of remains of land mammalia in marine tertiaries, as might easily be imagined from considering how large a proportion of the materials of these strata has been derived from the waste and detritus of the land, swept into the sea by inundations and rivers.

Bones of the mastodon have been observed in the subapennines of Italy; mastodon, hippopotamus, rhinoceros, lophiodon, horse, deer, hare, &c. in the shelly beds of Touraine;

hyæna, rhinoceros, elephant, sus, antelope, in the molasse of Estavayer; castor in the crag of Essex; chloromys, canis, in Volhynia; dichobune, palæotherium, in calcaire grossier of Nanterre and Provens.

From all this it is evident that the history of the terrestrial animals of the tertiary era is embarrassing, and not without great difficulty separated from that of the races of later date.

Their remains are chiefly preserved to us in lakes which may have existed through a long series of geological changes, and received and mixed together the exuviæ of animals living at widely different periods. Auvergne, for example, appears to have been dry land before the commencement of the tertiary period, and the various lakes of central France may be expected to contain traces of all the races of quadrupeds, which from the commencement of the tertiary even to historical periods lived on that ancient land. The geological date of many of the purely lacustrine tertiaries is entirely unknown; we may perhaps admit that the ossiferous deposit of Oeningen, from which Mr Murchison's fox was unearthed, is of date somewhat corresponding to the lacustrine beds of Weimar and Gmünd, and the post-tertiary deposit of Market Weighton, and may be sure that they are less removed from our own era than the fresh-water beds of the Parisian basin; we may perceive that palæotheria and other extinct genera of pachydermata belong to the older of the tertiary periods, while the elephant, hippopotamus, and felis were more numerous in later days. But, as far as can be at present known, there is no certain criterion of age to be found in the comparison of the fossil reliquiæ of land animals.

Igneous Rocks of the Tertiary Era.—In England and the

Parisian deposits, there is no trace of any irruptive igneous rocks of the date of the tertiary strata, though there are many great disruptions. The south of France is equally free from such admixtures among the marine strata between the Cevennes and the Pyrenees; but amid the ancient lacustrine beds of Auvergne volcanic rocks are abundantly effused. In Catalonia, volcanic phenomena on a smaller scale are noticed; the Euganean Hills, near Venice, are a more considerable example of igneous irruptions among marine tertiaries; the vicinity of Rome and Naples and the Val di Noto, shew abundant proof of volcanic action during this period. Hungary is also full of such monuments, and most of the trap-rocks of the Rhine, and various parts of Germany, probably belong to this era. It is not at all certain that the basaltic rocks of Ireland and Staffa and other parts of Scotland are not referrible to the tertiary period; certainly they are later than the chalk, which they have divided and overflowed.

The rocks which are thus referred to the tertiary era are principally trachyte and basalt; augitic and felspathic rocks greatly analogous to, or identical with, products of active volcanos. The appearance presented at the points where the igneous rocks have burst up are such as to leave no doubt that, in all the localities above named, the action was of the same kind as that exerted by an active volcano; the forms and grouping of the hills strengthen the analogy, and we finally must conclude that the igneous action developed over a great part of Europe late in the tertiary period, was in fact volcanic. In some cases, indeed, it is not possible clearly and certainly to separate the products of a modern volcano from those of the eruptions which took place in tertiary periods; as, for example, in Sicily and central France.

There is evidence that some of these tertiary volcanos burst forth in the sea, as the Euganean Hills, and spread lava over and amongst the strata then forming; in other cases, as in Velay, the eruptions happened amidst fresh-water lakes while the lacustrine sediments were accumulating. The volcanos of the Cantal appear to have followed the deposition of fresh-water limestones comparable to those of Paris and the Isle of Wight. It is perhaps doubtful whether any of the volcanos of this date broke forth in the midst of large tracts of land where no freshwater lakes existed; the Siebengebirge and other Rhenish hills of igneous rocks are no exception, for the Rheinthal has evidently been once filled with water many hundred feet above its present level, as the löss, the trass, and brown coal of the Eifel sufficiently prove.

The result of the researches of Daubeny and others on the subject of the tertiary igneous products, is to connect them, in a very particular manner, with the history of extinct and active volcanos of later date. In some instances it may be admitted that igneous action, which existed in the tertiary area, has been continued almost to historical times (Auvergne), or even to this day (Etna).

DISTURBANCES OF STRATA DURING AND AFTER THE TERTIARY PERIOD.

No more remarkable dislocations are known in the British islands than those two parallel anticlinal axes which broke up the tertiaries of the south of England. These have been already briefly noticed while speaking of the chalk formation. The northern axis, passing east and west from the Vale of Pewsey to near Folkstone, divides the basins of London and Hampshire, which are, in fact, de-

pressions parallel to this axis, from which the northward slope of the strata under the vales of Thames and the Kennet is extremely rapid, and affects equally the secondary and tertiary strata. It is therefore of posterior date to the last mentioned deposits. The southern axis passes east and west through the middle of the Isle of Wight, and is continued nearly in the same direction through the Isle of Purbeck toward Weymouth, where several great dislocations have been traced by Mr de la Beche and Dr Buckland. The northern slope from this axis is everywhere excessively steep, and, in the western part of the Isle of Wight, the chalk, plastic clays, and sands, and London clay, are absolutely vertical. What adds to the interest of this occurrence in Alum Bay, is the circumstance of the frequent lamination of loose variegated sands and interstratification of beds of lignite and layers of rounded pebbles. At a short distance northward, the depressed beds recover their horizontality, and the same is the case with the elevated strata on the south. Thus, it appears that two hollows and two ridges alternate, their axes being parallel; the northward slope being in both cases violent, and the southern moderate. These ridges are, in fact, scarcely to be called anticlinal axes produced by vertical elevation; they resemble more the effect of oblique movement of flexible masses. A singular effect is produced by the southern dislocation in the flints imbedded in the chalk. They are penetrated by secret fissures, and fall to pieces on being removed from their situations, an effect probably resulting from violent pressure on these elastic masses.

The geographical features of the south-eastern parts of England depend almost entirely on these great lines of disturbed strata, and we may from this learn to view, without

surprise, the greater phenomena of the same kind which have been brought to light by the labours of continental geologists. It appears certain that the Pyrenean chain has undergone elevatory movements since the deposition of some of the tertiary strata; the whole chain of the Alps has certainly been raised since the formation of most or all of the tertiary strata, for it bears upon several of its high crests, and in its mountain valleys, not only secondary, but also tertiary beds, as on the Righi and on the Diablerets according to Brongniart, and in the Valley of Gosau, according to Murchison. Parts of Sicily have also been uplifted, even since the deposition of rocks holding 95 per cent. of existing species, to an elevation of 3000 feet.

Besides those local and violent elevations, it cannot be doubted that the whole surface of Europe has been raised to various degrees by more gradual action, since the time of the formation of the marine tertiaries which fill the valleys of the Danube and the Rhine, the secluded basins of Bohemia and Hungary, and the great plains of northern Germany, Poland, and Russia.

The precise (geological) date of these elevations, whether violent or gradual, is one of the most difficult of geological problems; but it is certain that some happened during, and most of them subsequently to, the accumulation of the marine strata of the tertiary period. The general effect was therefore clearly to augment continually the dry land surface of Europe; to establish the various relations of fresh-water drainage at successive times; to permit the accumulation of fresh-water lakes; to allow of the conditions whereto the life of terrestrial and fluviatile animals is adjusted, and thus to offer analogies in all respects to the present order of natural causes and events.

RELATION OF TERTIARY TO HISTORICAL PERIODS.

Of all the classes or assemblages of aqueous deposits, that which is the nearest to our own days in point of date is the least exact in its boundaries and characters. While, concerning the older periods, the problem of the condition of the globe was principally confined to considerations relating to the sea, and thus the phenomena could be investigated according to fixed principles, applicable to at least the greater number of strata; the tertiary deposits compel us to enter also upon more complicated researches connected with the land: and, in discussing the history of still later phenomena, all the variations of physical geography assume still higher degrees of importance. The consequence is an amount of local diversity so great as to nearly annihilate all generality of result.

Moreover, the difficulties of this subject are augmented by a circumstance which is likely to become daily more and more influential on geological reasoning;—the want of a principle upon which to define the limit of least antiquity of this group of strata. What, in fact, is meant by supra-tertiary deposits? If we substitute for this term modern aqueous products, do we understand it the better? Or, attempting analysis, if we adopt as an equivalent expression the diluvial and alluvial accumulations, how are these to be defined? It is evident that here is a serious embarrassment.

What is meant by tertiary strata? If we should venture to include in this title all really marine deposits posterior to the chalk, even such as were only yesterday raised from the bed of the sea, it would be more intelligible than the methods now followed by geologists. For with the tertiary

strata of Europe begins that extreme *analogy* of the specific forms of organic life, that *identity* of generic conformation, which at once announces great and general differences of physical condition between them and the older strata, and equally great resemblances to the present order of things. Such results apply to marine, fresh-water, and terrestrial life; and, as far as yet appears, (but the evidence is very incomplete), nearly in an equal proportion to cach.

Moreover, the changes, to judge either by marine or terrestrial animals, which brought the extinction of old, and the creation of new races, were gradual. From the Parisian formations, containing 96 per cent. of extinct marine mollusca, and something like the same proportion of extinct land quadrupeds, to the Sicilian strata, which contain 95 per cent. of existing species of marine shells, and the lacustrine deposits of Oeningen and Weighton, in which the molluscous remains are wholly, and the quadrupedal reliquiæ partially, undistinguishable from living types, every intermediate term may be interpolated so as to constitute a real and complete series of monuments of the gradual substitution of one race for another.

Assuming, for the moment, this conclusion of the gradual change from the oldest tertiary to the actual phenomena of nature, supposing that all the organic and inorganic phenomena produced in the interval from the date of the cretaceous deposits to the present era, may be ranked in one great system, like those adopted for earlier periods, where shall we place the point of union between the modern or historical and the ancient or geological scales of time? In other words, To what part of the supracretaceous period shall we refer the creation of man?

To this important question impartiality must allow that

geology gives no clear and certain answer. Geology has no evidence on the subject that is at all of a positive character. We believe that the older stratified rocks were preadamitic for four reasons; because no trace of man or his works have ever been seen in them; because no remains of animals and plants occur in them which can be considered the same or very similar to the existing forms of life; because land quadrupeds generally are almost utterly unknown in them; because the physical conditions of the globe were entirely different from what we now behold.

Let us apply these tests to the supracretaceous deposits. In none of those which have been formed in the sea have we yet found the remains of man or his works; but remains of animals and plants, identical or very similar to existing kinds, are found even in the oldest of them; land quadrupeds occur both in fresh-water and marine strata which are among the earliest *eocene* tertiary deposits; and, finally, the physical conditions of the globe were, at the beginning of the period, very similar to the present, and this similarity continually augmented.

It is evident that all the probabilities point to the conclusion, that the creation of man, and all the new arrangements connected with that event, are to be placed in some part of the supracretaceous period; but in what part, is to be determined by further and cautious research. We cannot undertake to decide so important a problem upon the mere negative evidence of *the absence of human remains* from tertiary deposits, because such negative applies only to the European and North American tertiaries, none other being explored. Moreover, the deposition of human remains in marine tertiaries must be supposed to have been extremely rare and exceptional cases; nor could they be

expected to occur often even in lacustrine or fluviatile deposits. But, as before observed, this negation, however important, is yet only a local truth; human remains may yet be found in tertiary strata in other parts of the globe; nor would it excite surprise if, among 95 per cent. of existing species of marine mollusca in the Sicilian tertiaries, human bones should once be met with. Or if never in European regions this result should arrive, who is to assure us that, in countries more early peopled than these "far western isles," neither lakes nor estuaries of the tertiary era received and preserved some remains of man, or traces of his works?

As far as direct observation or satisfactory inference goes, every honest geologist will allow that he is ignorant of the point of union between the historical and geological scales of time: that the era of human existence, if recorded in geological monuments, has not yet been discovered among the small number which have been fully decyphered.

But, where certainty cannot be had, it is right to enquire into probabilities. It seems fair to admit, both with reference to historical testimony and sound views of the economy of creation, that the existence, in any country, of a considerable number of the animals which now contribute to the comforts and necessities of the human race, is evidence of the establishment, in that country, of the conditions within which Providence has restricted the existence of man. No created terrestrial being is capable, by natural constitution, of sustaining such variety of external physical conditions as man can brave through the exertion of those divine faculties which lift him above the inferior tribes of creation; if, then, the bones of the horse, the ox, the deer, the dog,—of hares, rabbits, beavers, foxes, and

other characteristic animals of the present creation, are found in lacustrine tertiaries, what is to prevent our receiving, as the *most probable indirect inference*, that the era of the creation of man had arrived when these strata were accumulated?

Let us adopt this inference though it be indirect, and, without further refinement, which the state of ignorance in which we really are forbids, let us admit that many of the lacustrine tertiaries are of date posterior to the formation of man and the present general arrangement of the terrestrial creation. We shall then class these and a variety of later marine and fluviatile deposits which have many characters in common, as SUPERFICIAL aqueous DEPOSITS of the most *modern* geological *period*, and consider them in relation to many contemporaneous products of subterranean heat.

SUPERFICIAL AQUEOUS DEPOSITS.

Resolved to conform, as much as truth permits, to the present views of geologists, from a conviction that they need rather a cautious limitation, than any essential change, —we shall adopt the following simple classification, suited to the condition of the land and sea in the modern geological period.

1. Marine deposits, . . (*a*) raised from the sea, or
   (*b*) yet in progress;
2. Detrital deposits, including (*a*) Erratic block group;
   (*b*) Ossiferous group;
   (*c*) Ossiferous caves and breccia;
3. Fluviatile and lacustrine deposits, terminated, or yet in progress;—and in each case endeavour to bring forward the history of the phenomena to the present date.

1. *a. Elevated Marine Deposits.*

Whether the Sicilian tertiary strata, containing 95 per cent. of existing species of testacea, should be ranked in this period, may perhaps be doubtful; but they furnish at least a point of departure, and shew us, on a great scale, the magnitude of effects produced by elevatory volcanic action. Just as these, and, in older times, the other tertiaries of the Mediterranean shores, were uplifted, and thus the ancient sea-bed was laid dry for man's examination; so we find, along the shores of the Baltic, the west coast of Scandinavia, the east and west coasts of Scotland and England, the south coast of England, the west coast of France, and the east coast of Ireland, as well as on the coasts of North and South America, proof of the partial rising of the land and neighbouring bed of the sea once, or several times.

Brongniart (*Tableau des Terrains*, 1829) has the merit of calling the attention of geologists to this phenomenon of local elevation of the bed of the sea. He gives a clear summary of the facts noticed at a great number of interesting points; and attributes the effects observed to a general lowering of the oceanic waters, which he supposes to have been the last of the great geological phenomena which have modified generally the relations of the outline and height of the lands to the area and level of the sea. In conformity with this conclusion, he carries back the date of such elevations beyond the historical era,—remarking that no trace of human reliquiæ occur among the gravel and shells of those elevated tracts.

The real date of many or most of these elevations must be allowed to be unknown; but the cause assigned by M. Brongniart is inadmissible, being contrary to physical pro-

babilities, and inadequate to the explanation of the particular phenomena.

English Shores.—One of the most remarkable examples is that observed by Mr William Gilbertson of Preston, on the coast of Lancashire, of which Mr Murchison gave the following notice at the York Meeting of the British Association. "The deposit consists, near the surface, of clay with bouldered rocks, covering great thickness of marl, gravel, and sand, the sand being usually the lowest. These accumulations are not only spread over the broad delta extending from the coast at Blackpool to Preston in the interior; but they rise at the latter place into considerable eminences, extending in plateaus on the banks of the Ribble and the Derwent for several miles inland. In certain places the marls, sands, and gravels contain shells of existing species (Mr Gilbertson enumerates above twenty species), not differing from those of the adjacent sea, above which they were found at various heights from 80 to 300 feet. The accumulations seldom offer proofs of regular bedding or tranquil deposit, but rather resemble the detritus found upon an agitated shore; although, in their diversity of structure, they present distinct evidence of having been heaped up during a long protracted period." (Among the shells we have seen Turritella terebra, Cardium edule, &c.)

Sir Philip Egerton has lately found a bed of gravel containing marine shells of recent species, at the Willington, in Cheshire, at the base of the "Forest Hills," seventy or eighty feet above the Mersey. This bed of ferruginous gravel and pebbles, *unlike the usual gravel of Cheshire*, was found to contain Turritella terebra, Cardium edule, Murex erinaceus, and others. *Over this shelly bed* was the ordi-

nary sandy diluvium of Cheshire, full of boulders of many rocks.

Mr Trimmer found marine shells (Cardium, Turritella, and Buccinum) in the sand and clay at Runcorn, several feet above the level of the tide, and under a deposit of peat, which was covered by sand and gravel.

Near Shrewsbury, Mr Trimmer has noticed marine shells of existing species (Turritella terebra, Cardium edule, Tellina solidula, &c.) in transported gravel and sand, resting on a peat-bog, which contains imbedded trees (oak, beech, and fir), and rests on gravel. On both sides of the Severn, near Shrewsbury, he found fragments of marine shells.

From these and other data, Mr Murchison has been led to entertain the opinion of the elevation of the whole line of country from Lancashire through Cheshire to Shropshire and the vale of the Severn, as of very recent date, compared to many other geological phenomena. (*Geol. Proceedings.*)

Mr Trimmer also collected from the summit of Moel Tryfane, near Caernarvon, 1000 feet above the sea, marine shells, " diluvial" sands, and gravel. The shells were fragmentary, had lost their gelatine, and consisted of Buccinum, Venus, Natica, and Turbo. The subjacent rocks are worn and scratched by friction of the transported pebbles.

On the east coast of the island, we have, in the valley of the Forth (according to Boué, Maclaren, &c.), terraces at some height above the water, containing Ostrea edulis, Mytilus edulis, Cardium edule, Turbo littoreus, Patella vulgaris, Donax truncatulus, and other littoral shells. Similar facts are noticed on the Clyde by Captain Laskey; on Loch Lomond by Adamson. On the Yorkshire coast, an excellent example of this kind of elevation of the bed of

the sea has been found on the lower part of the clay cliffs of Speeton. The yellow sandy beds here occurring have much the aspect of a really tertiary stratum, and contain Cardium edule, Tellina solidula, Amphidema depressum, in extreme perfection, without the least mark of violent agitation, either on the shells or on the deposit.

Farther south, the shelly gravel described in the *Geology of Yorkshire*, vol. i. as occurring in the southern part of Holderness, at Ridgmont, and Paul, though its irregularity of deposition seems to point to some difference of origin—to diluvial currents, rather than a mere elevation of a beach,—will complete our view of the subject. These sandy and gravelly beds rise to twenty or forty feet above the tide, and in their contorted and violently confused layers, among pebbles of all the northern and western rocks of Yorkshire and Cumberland, lie the strong shells of Turbo littoreus, Purpura lapillus, and Buccinum undatum,—the thin Mya arenarea, Tellina solidula, Tellina tenuis, and Mactra subtruncata, all recent shells of the German Ocean, and with them is an extinct shell. This shelly gravel passes under a deposit of peat and alluvial sediment.

Marine shells also occur in the gravel of Holme, on Spalding Moor, far inland, and a hundred feet above the sea.

Norway and Sweden offer considerable examples of these uplifted shelly littoral deposits. At Figa-elv, in the northern part of Norway, according to Ström, broken shells occur more than 150 metres (490 feet) above the sea. At Suroë and Tromsoë, further south, they occur a few metres above the sea: also near Drontheim.

M. Brongniart describes minutely the shelly deposits of Uddevalla, in the province of Gotheburg, on the west coast of Sweden. Here, in a little bay bordered with rocks

of gneiss, great quantities of shells occur nearly in a perfect condition, 70 metres above the sea (230 feet). The shells are those of the neighbouring sea. And to shew how truly the phenomenon indicates a relative change of level of land and water, M. Brongniart found *Balani still adhering to the gneiss rock;* proving the spot on which the testaceous animals are found to have been really the littoral bed of the sea.

The whole subject of the elevated beds of marine shells in Scandinavia has lately been investigated by Mr Lyell, who finds them near Stockholm, 30 feet, 70 feet, and 100 feet above the sea, in sand and gravel, or in marl resting on gneiss. In one place *a fishing hut* was found under 64 feet of shelly violet-coloured marls. The shells observed in the different localities were all residents of the Baltic, viz. Cardium edule, Tellina baltica, Mytilus edulis, Littorina crassior, Littorina littorea, Paludina ulvæ, Neritina fluviatilis (which lives in the Baltic). A land-shell, Bulimus lubricus, was also found. Near Upsala, thick clays, which lie over the gneiss and granite, contain Tellina baltica, Mytilus edulis, a small flustra and fuci, 60 to 80 feet above the sea. In a ridge of sand and gravel, a violet-coloured marl-bed, 80 feet above the sea, yielded Mytilus edulis, Cardium edule, Tellina baltica, Littorina littorea, Paludina ulvæ?

On visiting Uddevalla, the adherence of Balani was noticed in a new situation, with cellepora;—the quantity of shells lying in stratified clays, sand, and gravel, reminded Mr Lyell of Parisian tertiaries. Twenty-seven species of mollusca, and one echinus, were collected in a day. Among these are four zoophagous mollusca, not met with on the Swedish side, nor now existing in the Baltic, but found in the open sea. At several other ports on the western coast

near Gothenburg, marine shells, in beds of clay, and sand, and gravel, were found at different heights above the sea. They also occur fifty miles from the coast, west of Lake Wener. Thus it is evident that the bounds of the ocean have here been greatly contracted since the present species of testacea began to inhabit the Baltic and the neighbouring parts of the German Ocean. (*Phil. Trans.*)

Near St Michel en Lhermes (Charente inferieure et La Vendee), are three hills, situated six kilometres (about 1¼ mile) from the sea, about 1000 feet long, and their top 15 metres (50 feet) above the level of the highest tides. These hills are wholly composed of marine shells, solid in texture, with their colour preserved, and valves generally united, so as to indicate tranquil residence in the sea.

Near Nice, Risso has noticed perfectly preserved marine shells, in calcareous sand, 57 metres above the sea (150 feet.)

Near Maïta, in the Peninsula, between the Hellespont and the Gulf of Saros, Olivier reports marine shells in the friable grit: and the same are seen beyond the hill of Abydos.

According to M. Hertzog, as quoted by M. Brongniart, similar accumulations are seen near False Bay, Cape of Good Hope, 66 metres above the sea.

At Guadaloupe, St Domingo, on the coast of North America, on the western coast of South America, in the Red Sea, in Timor, and on the north-east coast of Iceland, the same phenomena occur,—the shells in all cases resembling those of the adjacent seas.

As far as regards the elevation of these shelly beds above the sea, either a gradual rising, or a sudden uplifting, will equally explain the greater number of cases; some may

suit with the one, and some with the other explanation. But the most important thing to remark is, that the shells have not been laid in their present situation by any sudden violence of water. Generally the great masses of diluvium, and the large and far-travelled boulders, which are supposed to indicate cataclysmal movements, *lie upon such shelly beds.*

In a few instances it may be reasonable to attribute the accumulation of the shells to currents set in motion by local convulsions. We should prefer this view for the phenomena of the southern part of Yorkshire, near Hedon, but are *sure*, on the contrary, that the Speeton sand-bed was formed under the sea; and adopt the same view for the phenomena in Sweden and Norway, the coast of Lancashire, the interior of Cheshire, the valleys of the Forth and Clyde, and indeed generally.

Who would have imagined, before Von Buch's and Brongniart's researches in Uddevalla, and Lyell's journey to other parts of Scandinavia, that so considerable a part of the coasts of the present islands and continents should be proved to have been the gift of subterranean movements, since the present race of marine animals were called into being? Yet, now that it is known, who does not perceive, in these modern phenomena, the consequence of the same causes as those to which geologists have long appealed for explaining the elevation of older sea-beaches,—like the English crag or submarine sediments, like the subapennine or Sicilian strata? Further, the inquiries of Mr Lyell in Scandinavia, as to the elevation of the coasts of that peninsula (*Phil. Trans.* 1835), go far to prove that the elevatory process is there still, however slowly, in action. However the yet disputed point of the uprising of the Chilian coast in 1822

may be settled, it is undoubted that many such risings, to a greater extent, have happened in those parts. The recent personal investigations of Mr Darwin have shewn that large tracts in Patagonia are nothing else than a sea-bed, raised in modern times, that is, since the creation of the present races of marine mollusca; and that strata of corresponding age form part of the double Cordilleras of the southern part of America. Thus, we are entitled to admit, among the effects of existing causes, *partial vertical movements* of the land.

b. Submarine Deposits still in progress.

Much of what goes on in the sea is entirely unknown to us. In fact it is only along the shores, at the mouths of rivers, and in shallow gulfs and seas, that we have any positive measures of the changes which take place in the bed of the mysterious deep. Nor have we yet obtained from the sounding line so much, or so exact instruction as nautical experience might furnish. How far into the sea currents of given velocity may transport sedimentary grains of given magnitude and specific gravity, is matter of calculation (Babbage); how far, in fact, the supernatant fresh waters can carry their earthy admixture, has been, in one instance, ascertained (River Amazons, Captain Sabine); thus we learn that sedimentary strata are really forming, with great regularity, over great spaces of the ocean bed; and this knowledge is of high theoretical value. But still it is to the shores that we must ever turn for data to serve as bases for comparison between modern and ancient marine deposits.

Here we see that the materials which the sea obtains from the wasting cliffs, rivers, and floods, are partly transported away by currents, and especially during storms, to considerable distances, but principally drifted coastways,

and deposited in times of tranquillity, or in retired situations, especially where the land is low and protected by far sloping banks, so as to augment incessantly the area of the low marshy tracts at the expense of the higher ground. In distributing the materials which fall from the cliffs, the agitation of the sea produces an effect of the same kind as the operation of washing a mixture of metallic ores and various spars; it separates the ingredients according to magnitude and specific weight,—the heavy and large masses are left on the beach for slow distribution over the sloping surface or gradual descent into the deep,—the coarse sand is urged onward by the tide, as a river pushes forward its bed, but the finer clays mix with the water, remain long suspended, and are carried to great distances, to be deposited wherever the sea stagnates, either by expansion over level surfaces, or opposition of the freshes.

It is evident that the modern deposits of the sea are pebbly where the agitation is great, sandy where it is moderate, and argillaceous where it is little.

In general, the deep sea deposits (exceptions may be necessary where currents of great force prevail in shallow seas like the German Ocean) must be of finer grain than those near the shore. The surfaces of contemporaneous deposition are slopes rising every where toward the shore, where alone they become, for a very short distance, steep.

What becomes of the calcareous matter swept down to the sea is not fully known. The formation of durable coralline and molluscous exuviæ from the sea will account for the consumption of much of this earth; and, in particular cases, Mr Lyell's remark of the formation of calcareous beds at the mouth of the Rhone will apply. But chemistry has not yet determined the *statical* composition of the sea, and, of course, it is utterly unknown what *variations* volcanic

eruptions, gaseous emanations, changing temperature, unequal pressure, and other causes, may occasion. Dredgings, soundings, and the experience of fishermen and divers in the German Ocean, Adriatic, and English Channel, inform us of the distribution of living zoophyta, mollusca, fishes, and crustacea, and of the parts of their decayed bodies. Certain tribes of mollusca, like the oyster, the coral, the mussel, inhabit limited breadths of the argillaceous, sandy, or rocky shores and shallows. Crustacea, pleuronectida, and other fishes, have their certain localities. The teeth of some fishes are noticed as being loose in the bed of the sea. The growth of the Coral Islands, if it be generally like that of the Bermudas, as described by Lieutenant Neilson (*Geological Proceedings*), offers greater analogies than might have been expected to the ancient zoophytic limestones, not only in the mass of matter, but in the irregular and partial distribution of the polyparia, the admixture of earthy and compact carbonate of lime, inclusion of shells, and partial stratification.

Could we raise, for inspection, the shallow German Ocean, the unequal depths of the Mediterranean, the Gulf of Mexico, or the base of some volcanic group of the southern ocean, what variety would meet our eyes! shelly deposits, coralloidal limestones, volcanic sediments, submarine lavas, strata of red and variously coloured clays and lignites,—almost nothing in common; contemporaneous difference carried to extreme; local diversity, overcoming all general agreement. Yet all the parts of this picture can be paralleled in the older marine deposits,—the only difference being a greater analogy of the contemporaneous effects,—a more decided and real relation of the phenomena to time; proof of the sequence of effects being due

to successive general changes of physical condition,—these changes continually altering the original aspect of nature, continually tending to diversify the uniformity and complicate the simplicity of the primeval state of the globe. Thus irregularity of surface, diversity of local phenomena, deviations of temperature, had always gone on augmenting till the globe assumed that inexhaustible variety of external conditions which harmonizes with its present rich adornment of vegetable and animal life, and continually excites and rewards the curiosity of the wonderful being who was placed by his Maker at the head of his last living creation.

2. DETRITAL DEPOSITS.

a. Erratic Block Group.

Since the time when the whole stratified crust of the globe was supposed to have subsided from a universal flood of water, the geological effects ascribed to the historical deluge, and other violent agitations of water, have continually diminished. It is not many years since we were familiar with the doctrine of the excavation of valleys and the accumulation of detritus over large surfaces of the globe being due to diluvial action; and now a large class of geologists, with Mr Greenough at their head, declare themselves "incapable of distinguishing between the effects of such a deluge or deluges, and subsequent phenomena produced by the ordinary agency of running water." There are geologists who would gladly expunge the word diluvial from our nomenclature, and instead of appealing to one or several general convulsions for the explanation of some striking fact, are willing to believe that small and

local forces, operating through long time, are sufficient for the purpose of geological speculation.

In many instances, we concede to these writers, that streams wandering in any required direction, over ground indefinitely variable in level, might, in the course of unlimited time, transport detritus in directions not possible during the present or any prior *statical* condition of the earth's surface. But who will grant these postulates for the purpose of avoiding the appeal to sudden and energetic disturbances of the relative level of land and water, that has seen the enormous dislocations of the carboniferous system of South Wales and the north of England, the prodigious and extended faults in the south of England chalk, imagined to himself the uprising of a chain of mountains like the Alps, or witnessed the enormous conglomerates on their flanks? And if a case can be adduced so circumstanced that those postulates must be rejected, on good geological evidence, what is to be done but to allow the alternative, viz. the occurrence of great and violent movements of large bodies of water, partial, though not general, deluges?

Such a case, it has been long supposed, was furnished by the examination of the dispersion of great blocks of the high Alps over Switzerland, and through the passages of the Jura into France; another example was found in the drifted sienites and limestones of Sweden, which lie in Northern Germany; a third in the transported masses from the Cumbrian mountains; a fourth in Canada.

The erratic blocks, as the larger boulders are called, which have been transported from the Alps, are most remarkable on the eastern face of the Jura, which looks towards the Alps, over the vale of the Arve and the Lake of

Geneva. On the Jura, 1500 feet to 2000 above the Lake of Geneva, crowning the hills and filling the valleys and rocky glens; in and around the Lake of Geneva and the valley of the Arve, as well as along the valleys which descend from the Alps, these blocks abound. It is observed that the blocks abound opposite to the embouchures of these valleys, and that distinct sets of blocks, derived from different mountains, have followed the lines of the different valleys. The blocks in the valley of the Rhine have come from the Grisons; those by the Lake of Zurich and the course of the Limmat were drifted from Glaris; blocks from the source of the Reuss have followed this river; the blocks of the Aar, and the slopes of the neighbouring Jura, have come from the ranges of the Oberland of Berne. From these facts, and the circumstance that the height to which the blocks have ascended the Jura is greatest opposite the valleys which descend from the Alps, no doubt can be entertained that the currents flowed from these mountains in many directions, and followed the line of the present valleys.

It appears the most probable view of these phenomena, that a general and violent convulsion of the Alps, while they were surrounded by water (whether fresh or salt we cannot decide), caused powerful currents to rush away from the axis of movement, bearing ice-rafts loaded with the loosened rocks. Thus might large boulders of particular rocks be accumulated in groups, as we find them on the Salève near Geneva, and in various parts of the Jura, or distributed in single masses over the vale of the Aar and the Lake of Geneva, then full of water, by the damming of the Rhine at Basle, and the Rhone at Fort d'Ecluse. Thus it seems conceivable that, in the agitation of the

movement of water, some rocks might find their way through the openings of the Jura into the plains of France.

This explanation appeared satisfactory to Venturi, reasoning on the phenomena of the south side of the Alps. It has been suggested from the case of the blocks on the drainage of the St Lawrence, and is proposed as the most probable view of the facts observed concerning the multitudes of rock masses which have crossed the Baltic, and dropped in heaps on the plains of Northern Germany, Poland, and Russia, from the Ems and the Weser, to the Dwina and even the Neva. These blocks are grouped in narrow elliptical areas, with the longer axis pointing north and south, or toward the Baltic; they often lie on the surface, especially the larger blocks, hardly ever at great depths. They consist principally of granite, sienite, porphyry, and transition limestones, with characteristic fossils which can be exactly paralleled in the southern parts of Sweden, and nowhere else. On crossing from Zealand to Scania, the traces of blocks reappear. The surface of Scania is covered with them; and farther north they abound in elongated hills called "Oasar" (analogous to the word "escar" in Ireland), ranging north-north-east to south-south-west. The blocks are more numerous on the Swedish side of the Baltic, nearer their origin, but not larger. Worn and polished surfaces among the primary rocks of Sweden are attributed to the transport of heavy bodies.

The dispersion of blocks from the Cumbrian group of mountains is extremely remarkable; and the example is more valuable to geology than most others of this nature, from the exactness with which the circumstances are ascertained. There are also peculiar relations of the tracks followed by the blocks to the ancient physical features of the country.

In the Cumbrian mountain group, the granites, sienites, porphyries, and metamorphic slates, are more or less peculiar in character, and easily recognisable. The granite of Ravenglass, on the western border of this region, has been drifted to the south, across the sea, along the flat or hollow of Lancashire west of the Penine chain, and over the plains of Cheshire and Shropshire, toward the vale of the Severn. In this long course, the quantity of pebbles and boulders of the Cumbrian rocks is considerable; and it is evident, that the currents, whatever they were, which carried the boulders, respected the present levels of the country, so far as never once to cross the Penine chain to the eastward, nor to penetrate far into the principality or the border districts, where, Mr Murchison assures us, the gravelly deposits are all derived from the neighbouring hills. From the eastern side of the Cumbrian mountains the porphyritic granite of Shap Fell, and the sienite of Carrock Fell, have been transported northward to Carlisle, southward by Kendal and Kirby Lonsdale, to beyond Lancaster, eastward over the vale of Eden, and up the Penine escarpment at Stainmoor, above Brough. Having here mounted the summit, the boulders diverge to the east by north, east and south-east, cross many lower ridges, traverse and descend the vales of York and Cleveland, and sweep over the oolitic moors and the chalk wolds to the sea-side at Scarborough and Flamborough-Head, a distance of 110 miles. In this passage three ridges of anciently elevated land, and two deep geologically ancient vales, were crossed: yet the water so far respected the elevations of ground now existing, as not to cross the Penine chain at more than one, and that *the lowest point opening directly to the west*, and to avoid the highest part of

the oolitic moors. What renders this more curious and complete is the circumstance, that one of the valleys crossed (the vale of Eden), 1000 feet below the origin of the granite; and 1000 feet below Stainmoor, is a valley caused by dislocation of the carboniferous system *prior to the new red sandstone era*, and the date of the dispersion of the blocks is since the newest tertiaries in the north of England.

If, however, following the indications of the phenomena, we refer, in every case, the dispersion of the blocks to the uplifting of particular mountain groups, and this is almost a certain inference, we may perhaps admit, in the neighbourhood of such groups, temporary variations, or *undulations* of the land, like those which accompany earthquakes, sufficiently extensive, when combined with the agitation of the sea, to permit the water to take, for a short period, directions previously and subsequently impossible. That the whole was the effect of a very short period, is the universal impression of all observers.

It is evident from all that has been proved, inferred, and admitted on the subject of the *erratic blocks*, that they were derived from particular mountain groups, drifted thence to limited, though considerable distances, along lines which respect the present levels of the country, both as to height and direction. They lie generally at the surface of the superficial marine diluvium, and speak plainly of great and violent convulsions. Yet it is already certain that they are monuments of merely local however violent disturbance, not proofs of universal or even very great or general floods.

From each mountain group, the blocks have gone in directions corresponding with its slopes and the configuration of the neighbouring country. Many local centres of

subterranean movement may thus have simultaneously or successively thrown off their rocky fragments; some of these, with other materials, were washed by the waves over surfaces momentarily changed in level by the concussion, others drifted on icebergs to great distances and quietly dropped on the surface. The phenomena, then, are merely a continuation of those which have been proved to occur in older times, with this difference, that *they* were for the most part performed in the sea, which reduced the products to a stratified form; *these* irregularly accumulated on the land.

Nothing in modern times so nearly approaches these effects, as the iceberg detached from glacier-covered shores in Arctic regions, floated hundreds of miles by oceanic currents, and dropping its load of rocks and detritus in distant regions. Could we witness the elevation of the bed of the northern ocean, would it not shew a group of detritus somewhat analogous to that of the erratic blocks; might we farther suppose the ice-borne detritus to be forcibly thrown over the land, would not the resemblance be perfect?

b. Ossiferous Gravel, Clay, &c.

Since the publication of Dr Buckland's valuable work, the "Reliquiæ Diluvianæ," and Cuvier's magnificent volumes, entitled "Ossemens Fossils," the attention of zoologists and geologists has been in an especial degree attracted to the superficial deposits containing bones of quadrupeds mostly extinct, and belonging to genera often no longer met with but in far distant regions.

These quadrupedal remains are found in gravel and clay, in caverns, and fissures, under various circumstances indi-

cating different mechanical and vital conditions, though still, by many geologists, ranked with erratic blocks under the one general and vague title of "diluvial deposits." This is certainly inexact, yet it is not to be thought that the arrangement has been founded on no real analogy; on the contrary, all that is yet known appears to shew that what have been called diluvial deposits, however different in origin, have all the common bond which in geology is most important, viz. time. For throughout all these deposits, the quadrupedal remains have a general uniformity of character, and a common degree of difference from the existing races of animals, which points to high antiquity, but not to the remote eras of the early tertiary deposits. Even a brief history of the discoveries in this field of research would fill a volume—even a mere selection of remarkable phenomena would occupy great space. The following notices are confined as much as possible to a short view of the principal results already obtained.

Ossiferous superficial deposits abound in Europe, Asia, and America; even far toward the polar circles (both in Asia and America). They consist of clay, gravel, sand, peat, marl, &c. sometimes accompanied by marine or fresh-water shells. Some of these are of comparatively modern date, and contain bones of existing races of animals; others belong to ancient times, and contain the remains of extinct tribes. It is to these latter that the name of diluvial deposits properly belongs; and though it is to be supposed that there are ossiferous accumulations of every age intermediate between the diluvial and modern periods, yet in many cases the following considerations will enable a geologist to pronounce whether a particular deposit falls within the proper meaning of the term diluvial.

There is no sufficient reason to class an ossiferous deposit of Europe as of the diluvial era, if its accumulation can be explained by the action of existing streams. But if amidst the mass of materials which it contains are fragments of rocks brought from other regions, in directions irreconcilable with the actual courses of streams, or any other courses of streams consistent with geological probability; if the quantity and mode of aggregation of these materials imply the violent and tumultuous movement of considerable bodies of water; and if the bones belong wholly or principally to extinct species of animals; more particularly, if bones of extinct species of elephant, rhinoceros, and hippopotamus occur, then it is most probable that the deposit may be rightly classed with diluvial accumulations.

In some cases, it is true, no certainty can be obtained whether the accumulation took place in the sea or on the land; whether the deposit is a raised beach, or a tumultuous accumulation on the land. Occasionally there is no distinction between gravel beds and erratic blocks; sometimes alluvial and diluvial formations are inseparably mixed; yet in many instances all these uncertainties vanish, and we are sure that we behold the accumulations from great floods which passed over limited ranges of the dried and inhabited land.

In the valleys of the Tyne, Wear, and Tees, the vales of York and Cleveland, the district of Holderness, the eastern counties, Norfolk, Suffolk, Essex, the vale of the Thames, the valley of the Trent, and the counties of Lincoln, Huntingdon, Cambridge, Northampton, Warwick, Stafford, Chester, Lancashire, not to mention many others, gravel of the diluvial character, often containing bones of extinct mammalia, abounds. In Ireland, in various parts

of France, Switzerland, Italy, and Germany, similar facts have been observed. In North and South America geologists have recorded the same experience.

In many instances the same districts yield lacustrine sediments, and peat deposits, so related to the ossiferous clays and gravel by position and organic contents, that they must be ranked as of the same age; frequently, also, we find in the limestones of the same regions, caves and fissures full of bones of the same extinct animals, and so circumstanced as to permit of their being added to the others as animals of a particular era. The most frequent of all these remains in England, and several parts of Europe and Asia, are the bones of fossil elephants; and from this circumstance we may name the geological period of their existence, in polar regions, the elephantoidal period, in contradistinction to the older or palæotherian period; it being always understood that these terms apply only to the land, and that we have good reason for doubt as to the practicability of referring the period which they designate to the general geological scale, depending on the succession of marine strata.

In consequence of the variety and celebrity of the ossiferous districts surrounding Kirkdale Cave in Yorkshire, we shall take this as an example of the deposits of the elephantoidal period in England.

The diluvial accumulations of Holderness, like all those of the eastern side of the north of England, consist partly of clay, partly of gravel and sand, all more or less mixed with fragments of rocks from different quarters. The clay in particular, usually of a brown or blue colour, is uncommonly full of pebbles and large boulders (from a hundredweight to a ton and upwards) of sandstones, limestones,

and greenstones, derived from western Yorkshire; slates, porphyries, and granite from Cumberland; diallage rocks, mica-slate, with garnets, gneiss, &c. and referrible either to Scotland or Norway, and many stones of whose origin no satisfactory account can be given. The aggregation of the mass is such as utterly to forbid belief that it was heaped together by any thing short of a mighty mechanical agency, which in its tempestuous violence permitted none of that distinction of specific gravity, form, or magnitude of the masses to appear in the deposit, which is invariably seen in every case of gradual or intermitting effect of ordinary streams and tides. In this clay lie bones of the elephant, rhinoceros, and hippopotamus, but not plentifully.

Above it and also below it, are gravels and sands far less replete with those proofs of wide and devastating waters, but sometimes more productive of bones and marine shells. Thus there is proof in this country of successive and different actions of unequally violent water flowing in various directions, with no regard to the lines of existing valleys or rivers, but with so much of a general reference to physical geography, as to have accumulated detritus in the great plains and broad vales more plentifully than on the hills.

This may be taken as a type of such phenomena in England and Ireland, where the detrital deposits are very extensive, and Scotland, which exhibits less of them.

Without attempting to trace the details of detrital deposits on the continent of Europe, we may observe that they are very extensive, yet not so general as was imagined (See *Reliquiæ Diluvianæ*). Certain districts, as for example the volcanic tracts of central France, shew nothing of the kind; others, as Normandy, the basin of Paris, the hills on the borders of the Rhine valley, the valley of the Rhine,

large tracts in northern Germany, in Italy, display similar phenomena to those in England. In every region it is found more or less easy to point out the direction of the diluvial waters concerned, and the result is a growing conviction that not one general, but many partial deluges rushing from particular centres, have occasioned the complicated accumulations.

In the eastern part of North America, Professor Rogers and Dr Bigsby agree in ascribing to the floods which have caused the boulders and gravel beds, a northward and northwestward origin. This is the most general result—combining, however, many different directions from different local centres—for Ireland, Scotland, and England. The Scandinavian rocks have gone south, south-east, and south-west; the Alpine boulders in all directions from the central axis.

In the north of Asia, and perhaps also the north-west of America, if we were to judge from the vast quantity of elephantine bones on the banks of the northern seas, the diluvial currents were towards the north; and it may hereafter appear possible to unite all these facts into one general conception—of the effects of an oceanic current, which may have been the resultant of many local disturbances, directed along opposite meridians and passing over the north pole; northward, up the Pacific and over eastern Asia; southward down the Atlantic, and over the west of Europe, and the eastern part of North America.

c. *Ossiferous Caves and Fissures.*

The preceding observations have established the facts of the land now existing as such in the northern zone of the globe, being inhabited by extinct races of quadrupeds,

during the detrital, diluvial, or clysmic periods of geological time. It is therefore in no degree singular that we should find in caves and fissures of the rocks in these same districts, additional proof of such occupation, and additional facts to complete our views of the then condition of the surface of the land. Through the researches ably prosecuted by Dr Buckland, and continued to the present day, the history of these remarkable repositories of the bones of the early land inhabitants of the northern zones is in a great degree known. It is certain, from these inquiries, that a great change has taken place in the quadrupedal inhabitants of Europe, northern Asia, North and South America, and Australia, apparently coinciding with the era or close of the period of detrital land deposits; for it is remarkable that the bones of extinct mammalia are almost unknown, while those of existing races are frequent, in deposits of more recent date.

The number of species of animals found enclosed in these natural rocky sepulchres is often greater than in the most prolific gravel deposits. It appears that the same cave has been resorted to both by extinct and existing races of quadrupeds, their bones being often situated so as to demonstrate that the former were entombed before or during the detrital era, the latter introduced at later periods. But often this distinction is imaginary, and no doubt can reasonably be entertained of the contemporaneous sepulture of certain extinct races, and some living species of quadrupeds. In fact, ossiferous caves are of various ages, and some were filled with bones in very modern times.

The bones of man, and traces of his ingenuity and labour, have been in several instances observed; generally under such circumstances as to indicate clearly their intro-

duction since the elephantoidal era; but in a few instances it requires something more than the direct evidence of the senses to be satisfied of this difference of date.

The distinction of ossiferous caves from fissures is sometimes real, often imaginary, and never of great importance in reasoning on the phenomena. Fissures are often denuded caves; caves are often but enclosed fissures. They are almost absolutely confined to calcareous rocks, vary wonderfully in size, shape, and detailed circumstances, and contain the same or different groups of animals, even in a small district. The condition of the bones in them is extremely various, and the inferences from all the known facts point to great diversity in the circumstances by which they have been introduced. The formation of the caves is generally not to be explained except by supposing original cavities, or superinduced fissures, to have undergone enlargement by the chemical action of acidulated water. In many cases water still flows through similar caves; in several ossiferous caverns and fissures, sediments and deposits are found which prove the *former* passage or percolation of water, though at present the subterranean drainage takes another course.

A very considerable proportion of the ossiferous caves yet known has been discovered on the banks of streams, or in cliffs against the sea; in some instances (Franconia, Kirkdale), the openings of caves known to have served as dens appear in situations so difficult of access, as to render it probable that the surface of the ground has been considerably worn away since the cave was occupied.

These ossiferous repositories have been found in the north and south of England, in limestone of different antiquity, as oolite and mountain limestone; in Belgium, the

south and south-east of France, in Franconia, Westphalia, Carniola, Hungary, along the margin of the Mediterranean, in North and South America, and Australia.

It is to be inferred from the various investigations of the condition and circumstances of these deposits, that the bones have been received into the caves and fissures in one of three modes.

1st, Some of the caves were occupied as dens during long periods, by ferocious and predacious beasts; as hyænas in England, bears in Germany.

2d, Into other caves and fissures quadrupedal reliquiæ were drifted by water.

3d, Some caves, communicating to the surface, appear to have received merely the bodies of quadrupeds which fell into them, or their bones moved from slight distances.

It will be sufficient to notice a characteristic example of each, and refer to Cuvier and Buckland for further and full details.

Kirkdale cave, described by Dr Buckland, contained on its long narrow level floor a bed of mud glazed over by stalagmite, and in this mud and in the stalagmite lay multitudes of bones of quadrupeds, especially of ox and hyæna, under such circumstances as left no doubt in the mind of its explorers that it was a den of hyænas, which for a long term of years roamed in the adjacent valleys, and dragged into this hiding-place the bodies of oxen, deer, and many other animals then living in the neighbourhood. The evidence for this opinion is very convincing, but it must be seen in the museums where the remains are preserved, not judged of from descriptions or figures. The broken and mangled state of the bones from this cave is exactly like what was seen in the similar hyæna cave of

Kent's Hole, Torquay, but directly contrary to the aspect of those from Banwell in the Mendip Hills, which was not tenanted by these destroyers.

As far as can be known, the bones of this famous cave—those of the marl beds of Weighton, and the diluvial clays of Holderness, are identical. The number of kinds of animals whose remains were found in the cave was twenty-four.

The remarkable cave of Gailenreuth, in Franconia, is a bear cavern, consisting principally of two large chambers varying in breadth from ten to thirty feet, and in height from three to twenty; the roof is hung with stalactite, and in the first chamber the floor nearly covered with magnificent pillars, mammillary masses, and sheets of stalagmite. Under this stalagmite lies a bed of brown loam and pebbles, mixed with angular fragments of rock, and teeth and bones. These latter were far more numerous in the next large cavern, which is on a lower level where the floor has been much broken up. In some lateral ramifications from this chamber, the number of bones imbedded in loam, or encrusted in stalagmite, is wonderful. "The upper part of the existing cave, and probably others which have been cut away by denudation, seem to have been the lodging places of bears that lived and died in them during the period immediately preceding the introduction of the mud and pebbles. The diluvial waters rushing into them, and the other similar caverns of Franconia, would introduce pebbles and mud, and would also drift downwards to their lowest recesses the bones that lay perhaps more equally distributed than at present." Stalagmite has since covered the mingled deposit. (*Reliquiæ Diluvianæ*, p. 136.)

The calcareous cliffs on the Mediterranean shores of Spain, south of France, Nice, Corsica, Sardinia, Dalmatia,

&c., abound in caves and fissures, and many of these are filled with a mingled mass of red loam, fragments of rock and bones of land mammalia,—frequently holding land shells,—rarely marine shells and zoophyta (at Villefranche.) Some of the caves have apparently been subjected to the action of the sea before and for some time after the introduction of the bones. (Christie and Pratt on the Cave of San Ciro near Palermo). Dr Christie supposes the breccia of San Ciro to have been deposited in water, and that the whole of the coast has since been uplifted from the sea.

As an example of a cave into which animals appear to have fallen, we may notice that of Banwell in the Mendip Hills (*Ann. des Sc. Nat.* IX.) The descent is made by steps ten feet deep into a small chamber about ten feet wide; from this a passage leads to a second chamber thirty feet broad, forty-five long, ten high. From the entrance into this large cavern, runs a cleft or fissure in a vertical direction to the surface. At the other end of this cavern is an inclined passage forty-five or fifty feet long, and at the entrance ten feet high, and very narrow, so that it is necessary to crawl on hands and knees; beyond the little chamber, which terminates this passage, it is impossible to proceed. The red loam containing bones of ox, deer, &c. seems to have fallen from the surface, through the fissures and the smaller anti-chamber. The bones are generally entire (or merely fractured) not at all worn or gnawed, nor do they otherwise give indication of having been accumulated by other causes than mere falling into an open fissure.

Valley, Fluviatile, and Lacustrine Deposits.—A certain class of fluviatile, or rather as we should wish to call

them 'valley' deposits, have attracted less attention than they merit. In some cases, as in Glen Roy, and certain valleys of Canada, terraces at particular and very elevated levels, range round the sides of the valleys, and mark, apparently, the ancient shores of an inland lake which has since burst its barriers. More frequently, as at the lower end of Glen Roy, and many other Highland valleys, on the Lune and other Cambrian streams, the Tyne, the Tees, the Yore, and almost all the other waters of the north of England, gravel terraces in the lower parts of the valleys, indicate the flowing of voluminous streams at higher levels in the direction of the actual river. This phenomenon, though little noticed, is really one of the most general we are acquainted with, and always bears in a very important degree upon the question of the origin of valleys, and often on the question of relative level of land and sea.

A different set of phenomena has been observed on the Rhine. That long valley in former geological periods had been dammed up at different points (Hibbert), and deposits (called Löss) of alluvial sediment have been formed along the margin of the elevated waters of the lakes thereby occasioned. The löss beds of the Rhine valley contain sand and fresh-water shells, and bones of elephants and rhinoceros (Horner, Lyell). What is called löss in Austria seems to be a similar deposit, and contains elephantine remains, (Murchison).

All the deposits above mentioned are of great antiquity; the löss of the Rhine valley rests, indeed, on the detrital gravel, but it is far removed from the date of the phenomena produced by the actual river Rhine.

The effects of actual rivers in the past and present economy of nature, admit of clear enunciation.

These effects are principally mechanical. In the early part of their course some streams drop carbonate of lime, others acquire it, but these effects are not important. The mechanical action of rivers, whether corroding or transporting, is proportioned to their velocity and volume; these are seldom combined except in particular great rivers like the Indus, the Mississippi, and the Rhine. The velocity is, for short distances, greatest in the upper parts of rivers; but their volume of waters augments toward the sea. Near their origin, rivers are both corroding and transporting agents; as they proceed, the former influence is often lost or compensated by the contrary process of deposition, the latter is weakened in most rivers, destroyed in some, but in a few maintained to the very conflict of the tides and freshes. (Captain Sabine's *Observations on the Sea Current of the Amazons.*) Rivers then, soon after their springs issue from the rock, begin to gather and transport sediment; but it is less by friction on their own beds than by the aid of atmospheric disintegration of rocks, and waste of the surface by rains, frost and glaciers, that they derive the matter which they bear along. According to the velocity of the stream, and the inclination of its bed, is the magnitude of the masses which it can drive forward. Few of the rivers of England, unless their waters be augmented by temporary floods, are swift enough to transport even moderate-sized gravel: sand, clay, and vegetable matters, constitute their principal sediments. But the torrents which rush down from the high Alps, roll along large quantities of detritus thrown into them by glaciers, water-spouts, avalanches, and eboulemens.

But the most stormy stream has intervals of comparative repose, and even the Arve and Rhone deposit most of their spoils within a few leagues of the mountains from

which they were torn. Frequently lakes interpose their tranquillizing waters, and receive and distribute the sediment of the river. These lacustrine sediments differ from the ordinary valley deposits of a river in their lamination, which radiates round the point where the river entered, and in deep lakes assumes a conical character. (Yates, *Ed. Phil. Journal.*) The dried beds of such lakes have a level surface, but not all plane surfaces in a valley have had this origin; on the contrary both the gentle rivers of England, and the rapid streams of more alpine countries, ever tend, by the shifting of their channels, and the equalizing effect of inundations, to distribute their sediments in planes, which fill the whole valley, and decline toward the sea with a slope corresponding to that of the river. Arrived near the sea, short torrents from alpine regions may throw rocks, pebbles, gravel, sand, and clay, in one confused mass, into the sea. But almost all the rivers whose path is long have left their coarser materials far behind; they have generally dropped much of their sandy admixture, and bring to the shore only fine earthy particles which could remain suspended in their less rapid waters. This is the contribution (principally) which the Po delivers to the Adriatic, the Ganges to the Bay of Bengal, the Mississippi to the Gulf of Mexico, the Nile and the Rhone to the Mediterranean; the Rhine, the Elbe, the Thames, and the Humber, to the German Ocean.

The mass of sediment thus brought to the sea is great; if delivered to the wide ocean and general currents (as in the case of the river Amazons, noticed by Captain Sabine) it may be carried hundreds of miles; but in still, land-locked seas, like the Baltic, Adriatic, and Bay of Bengal, the greater part is quietly dropped along the bottom and shores of the sea. Thus the extent of such gulfs and

basins is gradually and rapidly contracted, their depth reduced, and preparation made for a new series of stratified rocks, perhaps hereafter, in the manifold changes of the globe, to be raised for the contemplation of future geologists.

Thus we have the whole history of river formations; gravelly deposits near the mountains; sandy and argillaceous beds toward the sea; fine silt lands where the tides and freshes meet, in the estuary, and along the coast line. Thus the river mouths are incessantly advanced into the sea, the whole coast moves forward, and a large breadth of continually enlarging flat lands borders the tidal part of the river, and constitutes those rich and noble deltas, through which the changeful stream takes its winding way, and which require, in many instances, all the care and vigilance of man to preserve from the river and the sea, which made and may again easily overwhelm them.

The extent of some of these deltas is enormous. That of the Nile is small compared to some others; but, in fact, the gift of this river to the grateful Egyptians is much more than the delta; all the valley is full of its rich and far descended sediments.

The Delta of the Ganges commences 220 miles from the sea, and its base is 200 miles (Rennell.) This would be thought a considerable deposit, even among the old sedimentary rocks. The delta of the Niger is 25,000 square miles, (Dr Fitton, *Geology of Hastings*); an accumulation of timber and transported sediments (called a raft), on the Mississippi was estimated by Darby at 286, 784,000 cubic feet, being ten miles long, and eight feet deep, and this was the produce of fifty-two years mere decay of the timber on the banks of the Mississippi. (See Lyell.)

LACUSTRINE DEPOSITS.

These, like the caves, may be of almost any geological date; and it is, in fact, very difficult to decide on the claims of the different examples. It is probable that future geologists will choose to class together all the supracretaceous lacustrine deposits, and, by a general contemplation of them, arrive at valuable generalizations, which can now only dimly be foreseen. We shall offer four cases of lacustrine deposits in England and Scotland: the two oldest, of the elephantoidal era in England, and the mastodontic era in America; the next indicative of some different local condition of drainage, coeval with the existence of the Irish elk; the last descriptive of a deposit still in progress.

A remarkable occurrence of bones, in lacustrine marl, interstratified with the ossiferous diluvium of the vale of York, was fully explored by Mr Harcourt, and other members of the Yorkshire Philosophical Society. Resting upon gravel, and covered by gravel, near Market Weighton, was found a mass of fresh-water marls, to the depth of twenty-two feet, and in these lay bones of elephant, rhinoceros, horse, bison, deer, felis, wolf, birds, all, or nearly all, of extinct species. But with them lay thirteen species of land and fresh-water shells, exactly identical with types now living in the vicinity. No wearing, no unusual fractures, the teeth still in the jaws of the lion and the wolf, the bones of the leg of the horse nearly in their right situation, the horns on the skull of the ox, all the circumstances, in short, indicated a quiet deposition of the remains near the spot where the animals died. The north of England was then inhabited by elephants and lions. This part of Yorkshire was dry land in that era; and, as far as can be known, no change of level has since occurred.

The largest collections of bones of the mastodon, and other mammalia of the United States, occur in boggy grounds, called Licks, affording salt, in quest of which the herbivorous animals, wild and domestic, enter the marshy spots, and are sometimes mired. The most noted of these deposits is Big-Bone Lick, in Kentucky, occupying the bottom of a boggy valley, kept wet by a number of salt springs, which rise over a surface of several acres. The spot is thus described by Mr Cooper. " The substratum of the country is a fossiliferous limestone. At the Lick the valley is filled up to the depth of not less than thirty feet with unconsolidated beds of earth of various kinds. The uppermost of these is a light yellow clay, which, apparently, is no more than the soil brought down from the high ground by rains and land-floods. In this yellow earth are found, along the water courses, at various depths, the bones of buffaloes (bison), and other modern animals, many broken, but others quite entire. Beneath this is another thinner layer of a different soil, bearing the appearance of having been formerly the bottom of a marsh. It is more gravelly, darker coloured, softer, and contains remains of reedy plants, smaller than the cane so abundant in some parts of Kentucky, with shells of fresh-water mollusca. In this layer, and sometimes partially imbedded in a stratum of blue clay, very compact and tenacious, are deposited the bones of extinct species."—(*Reports of Brit. Assoc.*)

Mr Cooper has been at the pains to compute, from the teeth and other parts known to have been removed from Big-Bone Lick, the number of individuals requisite to furnish the specimens already carried off.

Mastodon maximus, . . .	100	individuals.
Elephas primigenius, . .	20	......
Megalonyx Jeffersonii, , .	1	......

Bos bombifrons, ...	2 Individuals.	
Bos Pallasii, ...	1	......
Cervus Americanus, . . .	2	......

Subterranean Forests, as they are termed, abound on many parts of the English and French coast. (See De la Beche's *Manual.*) The phenomena are not precisely alike, but yet generally similar in all of them. Some of them shew signs of having been prostrated in particular directions, and covered by river sediment (Tees Mouth, Lancashire, near the Humber); others are composed of drifted hazels, yews, oaks, pines, alder, &c., and covered by pine-stumps in attitude of growth (Waghen near Hull); many are extensive accumulations below the level of the sea (Frith of Tay, Swansea, Humber Banks); some are slight aggregations in old lakes (Holderness). Very often layers of blue clay, with shells of existing fresh-water mollusca, lie with peat and timber in old lakes (Holderness). Sand underlies the woody deposits of Mount's Bay; clay, of unknown depth, is the base of that on the Frith of Tay; river sediments support that of the Cambridgeshire fens; and "diluvial" clay that of Holderness. Bones of the Irish elk lie in old lakes, partly full of peat and shelly clay, in Ireland, the Isle of Man, Lancashire, and Holderness; but the more common characteristic osseous reliquiæ are those of the *stag or red deer,* fallow deer, beaver, and other existing quadrupeds, birds, insects, &c. Movements of the land are commonly thought necessary to explain the position, and particularly the *level,* of these "forests."

Shell-Marl.—The best example was furnished by Mr Lyell's description of Bakie Loch, Forfarshire, which agrees remarkably with some marl deposits in Tweeddale. Here, under peat with trees, shell-marl of variable thickness and consistence occurs, resting on a loose or partially cement-

ed sand. Under this is another bed of shell-marl, of an earthy consistence; then fine sand and detritus. Near the springs which enter the loch, and supply the calcareous matter, the marl assumes greater consistence, and, from its compact or crystalline substance, deserves the name of "Rock-marl."[1]

Table of the Distribution of certain Extinct Quadrupeds.

Names of Species.	Some Localities in Caverns, Fissures, &c.	Some Localities in Alluvial and Diluvial Accumulations.	Locality in or amongst Marine Strata.
Felis spelæa,	Kirkdale, Gailenreuth, Luel Vieil, Sundwich, &c.	Weighton, Val d'Arno.	
Hyæna spelæa,	Kirkdale, Kent's Hole, Fouvent, Sundwich, &c.	Lawford, Val d'Arno, Kostriz.	
Canis spelæus,	Kirkdale, Franconia, . .	Weighton.	
Castor, .	Luel Vieil, .	Val d'Arno, .	Near Zurich.
Megatherium Cuvierii,	. . .	Buenos Ayres.	
Elephas primigenius,	Kirkdale, .	Val d'Arno, Weighton, Essex, Norfolk, &c. &c. and throughout Europe, North of Asia, and America, .	Volhynia, Warsaw, Wielicska, Estavayer.
Mastodon maximus,	. . .	South America.	Italy, Touraine.
Mastodon angustidens,	. .	Val d'Arno, Austria, Peru, . .	Touraine.
Hippopotamus major,	Kirkdale, .	Val d'Arno, Essex,	
Rhinoceros leptorhinus,	Franconia, Kirkdale, Nice, .	Siberia, England, Germany, Val d'Arno.	
Cervus megaceros,	Kent's Hole, .	Ireland, Rheinthal.	
Bos primigenius,	General, . .	Frequent.	

[1] See Lyell in *Geol. Trans.* vol. ii. 2d Series, *Principles of Geology,* and De la Beche's *Manual.*

Remains of the human race have often occurred in the same repositories as the animals noticed above, but almost never without sufficient proof of their later existence. In some cases distinct proof of inhumation at subsequent periods, in other cases different state of conservation, or different situation in the ossiferous deposit, have removed all doubt of this important fact. The only cases which can be considered at all doubtful, are those mentioned by MM. Tournal, Teissier, &c. in caves of Bize, &c. in the vicinity of Narbonne. In these instances, the *proof* of the posterior date of *all* the human reliquiæ seems incomplete; but the balance of *opinion* appears to be decidedly in favour of the view which has so long been adopted by geologists, viz. that these northern regions were not inhabited by men during the period when elephants and hippopotami roamed in the damp forests of Germany, France, England, and Siberia.

What is the exact *geological date* of the existence of man, in other words, what is the exact point of union of historical and geological time—a most important problem—is therefore as yet wholly undetermined. Its solution must, probably, be looked for in countries nearer to the tropical regions of the Old World, where many concurring circumstances unite with the authority of Scripture in fixing the local origin of our species.

IGNEOUS ROCKS AND DISTURBANCES OF THE MODERN PERIOD.

The effects of subterranean heat have been exhibited at intervals in all the periods of geological time, measured by the deposition of stratified rocks; the resulting phenomena have been noticed at so many points on the earth's surface,

as to leave no doubt that the action of heat, below the surface of the solid crust of the globe, has been, either contemporaneously or successively, as extensive as that of water above it. Certain phenomena, such as the general character of composition and the absence of organic remains, in the lowest primary strata, lead to the impression, that in the most ancient known geological period the effects of heat were at one and the same time coextensive with these strata, which is nearly the same thing as saying they were contemporaneously universal. But as we ascend in the order of strata, and come nearer, though by an unknown progression, to the modern era, the evidence of this contemporaneous great extent of the subterranean caloric influence diminishes; the effects are still striking and of the same general description and equal in violence, but more local and limited. In the older period, we found occasional interstratification of igneous rocks and marine sedimentary rocks, and other proofs of the submarine situation of the igneous agency; but in the tertiary periods new phenomena were observed, which proved the igneous agency to have burst forth on the dry land, or amidst fresh-water lakes, and to have assumed in consequence much of that peculiar character which belongs to actual volcanoes.

It is very evident that the study of volcanic action affords the only clew to a correct appreciation of the circumstances under which igneous agency exerted itself in ancient times. The exhibition of modern volcanic action takes place under a sufficient variety of circumstances to furnish an adequate basis of reasoning upon the conditions which influenced the different effects of similar agencies in earlier periods.

VOLCANOES.

The antiquity of volcanic phenomena is very great. Most of the districts in which volcanic phenomena take place, or have left evidence of their former activity, appear to have been vents for subterranean fires from the era when the district first rose above the sea. This appears certainly to be the case with Sicily, Auvergne, Naples, the Rhenish volcanoes, and many others, though perhaps the present volcanic cones of Etna and Vesuvius may not be of such high antiquity. Many truly volcanic regions no longer contain burning mountains, and never yield streams of lava; yet by the nature of the rocks, by the phenomena of mineral springs, by the mere form of the surface, they yield evidence that volcanic forces once were active there, though now extinct, dormant, or called off to some other focus of energy. From what we learn by comparison of volcanic regions in different conditions, it appears that each volcanic vent has a definite date of origin, lives through a period of activity, and decays by gradual or intermitting stages, till nothing is left but the marks of what has been.

Continuity of Volcanic Action. This decay and extinction of volcanic vents is a phenomenon of the highest importance in reasoning on the condition and causes of the subterranean temperature. If volcanoes die away for lack of their chemical fuel, a presumption arises that the conditions of their excitement are local, limited, and exhaustible; but if this be not the case, if volcanic action only sleeps below a certain point, because it is awakened to greater and more easy manifestations elsewhere, there is no reason *à priori* to prevent our admitting for all volcanoes one general physical condition or cause.

Extent and Connection of Volcanic Action. Now it is

certain, that in several instances volcanic phenomena have happened simultaneously, or rather after a short interval, at very distant points or foci of volcanic energy. Dr Daubeny observes (*Treatise on Volcanoes*), "The connexion of the volcano near the town of Pasto with those of the province of Quito, was shewn in a striking manner in 1797. A thick volume of smoke had proceeded, ever since the month of November 1796, from the volcano of Pasto, but, to the great surprise of the inhabitants of the city of that name, the smoke suddenly disappeared on the 4th February 1797. This was precisely the moment at which, 65 leagues further south, the city of Riobamba, near Tunguragua, was destroyed by a tremendous earthquake."

Humboldt (*Personal Narrative*) appears to view the higher part of the kingdom of Quito and the neighbouring Cordilleras, not as a group of distinct volcanoes, but as an immense volcanic mass, stretching from north to south, and occupying a surface of more than 600 square leagues; the lofty mountains of Cotopaxi, Tunguragua, Antisana, and Pichincha, affording so many apertures from which the fire finds vent, sometimes in one and sometimes in another.

No doubt exists of the connection of earthquakes and volcanoes. Mr Lyell observes, that from the commencement of the thirteenth to the latter half of the seventeenth century, no earthquakes are recorded in Syria and Judea; and during this interval of quiescence, the Grecian Archipelago and the coasts of Lesser Asia, Southern Italy, and Sicily, were shaken by earthquakes and alarmed by eruptions.

Geographical Distribution of Volcanoes. But much stronger proof of the great extent and connexion of the conditions of volcanic excitement, is to be found in the

view of their positions on the globe. Von Buch was the first to propose a classification of volcanoes in two groups, viz. *central volcanoes* and *volcanoes in line*. Those of the Italian shores and islands, Iceland, the Azores, Canary Isles, Cape de Verd Islands, Gallapagos, Sandwich Islands, Marquesas, Society Islands, Island of Bourbon, as well as the mountains of Demavend, Ararat, &c. belong to the former class. The Greek Archipelago, the west of Australia, the Isles of Sunda, the Moluccas and Philippines, Japan, the Kurilian and Kamschatkan chains, the Aleutian Isles, the Marian Isles, the Antilles, as well as the Cordilleras of Chili, Quito, Guatimala, and Mexico, are ranked with the latter.

The extinct volcanoes of the old world, Auvergne, the Eifel, Northern Germany, Hungary, north of Italy, &c. belong to the class of central volcanoes.

The most remarkable line of volcanic vents on the globe, is that long chain of islands which, from Alaska, on the coasts of Russian America, passes by the Aleutian Isles, Kamschatka, the Kurilian, Japanese, Philippine, and Moluccan Islands, and then turns in a long course through Sumbawa, Java, and Sumatra, to Barren Island in the Bay of Bengal.

Active and Extinct Volcanoes. The most common division adopted in works on volcanoes separates the known volcanic districts into extinct and active volcanoes,—a distinction which seems clearer than it is; for between the burning mountain with its formidable realities, and the long silent volcanic mound, surrounded by mineral springs, and other residuary phenomena, almost every gradation can be traced. Viewing the subject generally, it is difficult to resist the idea that the exhibition of volcanic excite-

ment is in proportion to the proximity of the sea, or other repository of water; for almost every one of the active volcanoes of the globe is situated in an island, or near the sea-coast of a continent, and many of the extinct volcanoes are on the site or in the neighbourhood of ancient lakes now dried up. The following short synopsis of the situation of active volcanoes, will shew their general proximity to the sea.

In the islands and sea-coasts of Europe.—Etna, Vesuvius, Stromboli, Volcano; several in Iceland, Jan Mayen, Santorino.

In islands of Africa.—Teneriffe, Lanzerote, Cape Verd Isles, Azores, Isle of Bourbon, Madagascar.

In islands of Asia.—Zibbel Teir in the Red Sea; an island in the Sea of Azoph; Aleutian Islands; Kurile Islands, Loo Choo, Formosa, Lucon, Fugo, Mindanao, Celebes, Ternate, Fidore, Sumbawa, Java, Sumatra, Barren Island, Banda, New Guinea, New Britain, New Ireland, Friendly Islands, Society Islands, Ladrone Islands.

On the continent of Asia, near the coasts or inland seas.—Demavend, Kamschatka.

America, in the islands.—West Indian Islands, Gallapagos.

America, near the coast.—California, Nicaragua, Guatemala, Columbia, Peru, Chili.

America, more inland.—Mexico.

The principal volcanic tracts of Europe, which all belong apparently to the tertiary and modern periods of geology, are those of the Puy de Dôme, Cantal, and Velai in France; of the Eifel; the Rhine below Andernach, near Heidel-

burgh, and near Freyburg; the Vogelgebirge; Rhongebirge; Eisnach; north of the Lake of Constance; Hungary; Transylvania; the Grecian Archipelago. (See Daubeny on Volcanoes.)

Origin of Volcanic Vents. The origin or production of a new volcano has seldom been witnessed by competent observers. The phenomenon is, in fact, extremely rare; for though we read of new cones and craters being formed on Etna, and new islands occasionally raised from the sea, the fact in general is, that these are merely new vents to an old volcano, whose former and accustomed channels to the surface have by some circumstances been rendered incapable of giving passage to the vapours and lava of the teeming mountain. It is probable, from considering the lines of craters which belong to one of Von Buch's classes, that some great fissure or line of subterranean movement has determined the local situation of volcanic vents. Even the central volcanoes of Von Buch appear to be often related to particular centres and axes of subterranean movement; as Auvergne, the Eifel, Sicily, and others.

Origin of Volcanic Cones and Craters. Von Buch supposes in addition, that many volcanic mountains have been formed by uplifting of stratified and igneous masses into a conical or elliptical mass depressed in the centre, and to such he gives the name of Erhebungs Cratère (craters of elevation).

Mr Lyell controverts this view, and attempts to prove that, like many of the new cones of Etna, Monte Nuovo, &c., near Naples, volcanic mountains generally are craters of eruption, that is, nothing but heaps of scoriæ and ashes, and streams of lava, collected into a conical mass in consequence of issuing from a central orifice. Many volcanic

mountains, probably all of a very decidedly conical shape, are formed in this manner; but certain dome-shaped hills in Auvergne are held by Dr Daubeny to be strictly referrible to elevation in mass. It is supposed that the formation of the Mexican volcano of Jorullo (1759), when, according to Humboldt, the ground rose up like a bladder for a surface of three or four square miles, to a central elevation of 324 feet, is a modern example of the truth of the hypothesis of Von Buch; and at all events, the possibility of such an origin cannot consistently be denied, if we pay attention to the many instances of elliptical elevation of stratified rocks of different ages, as at Woolhope in Herefordshire, Greenhow Hill in Yorkshire, &c. which have been brought forward of late years.

Volcanic Phases. By whatever means a volcanic vent, whether it be a cone with a crater-shaped top or any other aperture, has been formed, its augmentation can only take place by the process of eruption. Scoriæ, ashes, &c. blown from the mouth fall round and augment the cone; streams of liquid rock flowing over the edge of the crater, may, by many successive currents in different directions, produce an equal conical mouth of concrete lava, or, rushing out from the side of the cone, spread or accumulate according to the shape of the surface. These effects must differ according as the phenomenon happens in the sea or on the land. Hence Mr Scrope's distinction of subaqueous and subaërial volcanoes. Subaqueous ejections of scoriæ, &c. are subject, in the first place, to partial suspension in water, and in the next, to agitations of the liquid produced by the eruption and other causes. These act in the same direction, and tend to *diffuse* the disintegrated accumulations far and wide from the volcanic vent. Hence strata

of very small inclination are produced round the crater, or, if any thing comparable to a volcanic cone is occasioned, the heap of large scoriæ must yield to the lateral influence of the waves, and be at length dispersed over the bed of the sea. Of the truth of this view, the modern island of Sciacca, its rapid growth, and rapid degradation, offered good illustration.

Subaqueous eruptions of lava must also for the most part flow under the pressure of the liquid columns to various breadths on the bed of the sea, so as to form irregular stratiform masses, embossed here and there by mounds of lava, too quickly congealed to spread into the tabular form.

Thus it appears a necessary consequence of the conditions of a subaqueous volcano, that its accumulations, whether liquid or disintegrated, should be formed into broad expanded masses, having a stratiform arrangement; and this is what is always observed among the igneous rocks of ancient geological periods, unless where fissures in the rocks are filled by the irruptive lava. Thus the basalt of Teesdale and of Antrim, the porphyritic masses of Snowdonia, Cumbria, &c. have been formed.

Subaërial ejections of loose materials must of necessity be collected round the point of exit into conical layers, determined in their angle of inclination *by the angle of rest of the particles*, under the influence of the forces of projection and gravitation. The lavas poured out from the crater, or bursting from the flanks of the cone, must accommodate themselves to the form of the surface, so as to mantle round the original mountain, swell into knolls at its foot, or flow away into valleys and hollows of the land, or enter the sea. All these variations are visible at Etna and Vesuvius.

Subaërial volcanic ejections may alternate with fresh-

water productions (Cantal), with detritus holding bones of mammalia (Auvergne), or cover cities, as Pompeii and Herculaneum; and submarine volcanic accumulations may alternate with shelly sediments and limestones.

But there is yet another form of modern volcanic aggregates which it is of great importance to distinguish from the preceding, because of its bearing upon points of great importance in old geology. There are *subterranean volcanic products* which neither are poured into the sea nor thrown into the air, but secretly elaborated under the pressure of a solid covering, and effused into the fissures of the rocks.

Although it may reasonably be allowed that the great variety of productions ejected by subaërial volcanoes affords a good indication of the principal mineral substances generated by volcanic action, we must be cautious not to limit our notions of their combinations in the deep parts of the earth to those which are suggested by the compounds which are determined at the surface.

The degree of pressure, rate of cooling, and mass of ingredients, which are known to be important modifying conditions of molecular aggregation, are wholly different at the roots and about the surface of the immense volcanic chimneys which, like Etna and the Peak of Teneriffe, become filled with the liquid rocks whenever the subterranean pressure amounts to a particular degree.

At the base of a volcanic vent, deep in the earth or under the sea, particular mineral aggregates, slowly cooled, under great pressure, and in great masses, may, and probably do, at this day assume the largely crystalline texture and distinctness of ingredients of granite; on the bed of the sea they may flow in the state of porphyry or basalt;

on the surface of the land appear as porous lava, and be blown into the air in disintegrated scoriæ, ashes, and dust.

VOLCANIC PRODUCTS.

The number of mineral substances found in volcanic ejections is very great. Nearly 100 distinct minerals have been recognised among the products of Vesuvius. But of these only very few occur in such abundance as to constitute any great portion of the lava or scoriæ.

It is almost correct to say that the principal portion of the masses of all the known volcanoes is constituted of two minerals,—felspar and augite.

According to the predominance of one or other of these ingredients, the lava currents may generally be classed as felspathic lava, or augitic lava, but the permutations of ingredients is so frequent, that no definite mode of specific nomenclature has more than a local value. Mr Scrope forms the groups Trachyte, Graystone, Basalt, and in each proposes many subdivisions. Trachyte is divided by Beudant upon different principles. Perhaps it is useless to attempt the drawing of lines where nature has permitted none to appear. Trachytic rocks, as in the Siebengebirge, Hungary, Auvergne, are composed of crystals of glassy felspar alone, or mixed with mica, hornblende, titaniferous iron, &c. and confusedly aggregated or cemented by compact felspar. Porphyritic trachyte, like porphyritic granite, holds large crystals of felspar (Siebengebirge.) On the other hand, in the graystone of Mr Scrope augite or hornblende, or both, predominate over the felspar. In many cases the felspar is partially or entirely replaced by other minerals, as leucite, melilite, hauyne, olivine, &c.

According to the rate of cooling and other circumstances,

the aggregation of these ingredients varies much. Lava which has flowed down into water, and been consolidated under even slight pressure, is found more condensed than that which has hardened in air, and become cellular by the free extrication of gaseous bubbles in the hot mass. Sudden cooling of lava gives it a glassy character, as obsidian, arlstone, &c.; slow cooling developes its crystalline, granular, and earthy texture. Gaseous expansion in a fluid mass of lava may convert it to cellular pumice, or scatter it into dust or scoriæ, which are thrown out of the crater.

Again, the scoriæ and dust are often collected by water into sedimentary deposits, called volcanic tuff, conglomerate, puzzolana, and trap. It is this kind of accumulation which covers Herculaneum, while Pompeii seems to have been buried in dry ashes.

Besides the solidifying mineral aggregates which flow over their summits or burst out from their flanks, and the disintegrated showers of scoriæ and ashes which fall round them, many volcanoes pour out floods of water, variously impregnated with salts, and mixed with earthy sediments; and all discharge volumes of gaseous matter and steam, and sublimed mineral substances.

The gases are chlorine, sulphuretted hydrogen, sulphuric acid, carbonic acid, nitrogen, (Daubeny). Sir H. Davy found the sublimations of Vesuvius to be chloride of sodium, chloride of iron, sulphate of soda, chloride of potassium, sulphate of potash, oxide of copper, chloride of cobalt.

PHENOMENA OF EXTINCT VOLCANOES.

Long after volcanic fires have ceased to be visible externally, the regions which they once desolated are the theatre of residuary phenomena of considerable importance. In

the neighbourhood of Vesuvius the ancient trachytic crater called the Solfatara, is still the channel through which come to the surface abundant vapours of sulphuretted hydrogen. Hot waters still gush out from the Monte Nuovo and the Lago Agnano. Carbonic acid gas still fills the Grotto del Cane, and rises with the springs of water in Auvergne and the Eifel. Earthquakes have often ravaged the districts of Asia Minor, where, in very ancient times, volcanic fires were lighted: and, by combining these and other indications, we find that it is rather from want of communication to the surface than from any real stifling of their energies, that volcanoes appear to become extinct.

If we were to admit, with Dr Daubeny, that the phenomena of hot-springs indicated a slow volcanic action still going on below the point of efflux (and the arguments he has brought from the gases which they evolve[1] appear important), it would follow that few districts of the globe are exempt from such slow action of volcanic forces below them. But, on considering the cases where the same gases are evolved from cold springs, Harrowgate, Tunbridge, &c. we find ourselves conducted to a more general result, viz. that in places where *disturbed stratification* occurs, or vertical movements have happened, such as to render it certain, or very probable, that a communication, arising from solution of continuity of the strata, exists from the surface to great depths, the springs which issue have generally a saline muriatiferous or mineral impregnation, and evolve gases, (sulphuretted hydrogen, azote, carbonic acid,) which correspond to those of volcanic regions, and indicate that, at the present day, at some depths from the surface, the chemical agencies consequent on volcanic action or high temperature are con-

[1] *Report to the British Association.*

tinually going on, or momentarily excitable. The temperature of such springs may perhaps be a good indication of the nearness of the source of heat, provided allowance be made for the quantity of water issuing.

CONNEXION OF EARTHQUAKES AND VOLCANOES.

That such a connexion exists is perhaps universally allowed; but it is also capable of sufficient proof that earthquakes generally precede volcanic eruptions, and this sometimes for a considerable period, increasing in violence until the eruption happens and relieves the subterranean pressure.

On the 26th of March 1812 Caraccas was utterly destroyed by an earthquake, and a mountain near it subsided. On the 27th April the eruptions of the Souffrier, in St Vincent's, began.

In the year 63 of our era earthquakes began to disturb the vicinity of Pompeii, and in 79, after a succession of these phenomena, the fires of Vesuvius were rekindled.

The extraordinary eruption of Jorullo in 1759, followed upon extraordinary earthquakes; and the unparalleled excitements of Skaptar Jokul in 1783, were heralded by similar precursors.

The elevation of Monte Nuovo in 1538 was, in like manner, indicated by previous violent subterranean disturbances.[1] The connexion of earthquakes and volcanic eruptions is that of two effects of one cause. In the Canary Isles, the Peak of Teneriffe is almost a continual safety valve, which drains off the gases, &c. and so frees the surrounding islands from earthquakes.

Earthquakes.—These alarming indications of subterra-

[1] See Lyell's *Principles of Geology.*

nean disturbances are far more extensively felt than in the mere vicinity of the volcanic cones, whose renewed activity they often betoken. The numerous concussions which were experienced in England in the 11th, 12th, 13th, 17th, and 18th centuries, seem as much dependent on the Icelandic as on the Italian volcanoes. Those which have affected all the countries north of the Mediterranean; the convulsive movements of Asia Minor in the early Christian eras; those of India, are far removed from any centres of volcanic excitement. We also find that, in some instances, earthquakes have prevailed for years, and done great mischief, (as before the earliest recorded eruptions of Vesuvius) before the throes of nature have been relieved by the birth of volcanic fires. Hence, it appears that the earthquake is really the greater and more general, and the volcano the lesser and more limited, effect of a cause more general than either.

The characteristic effect of earthquakes is the displacement of the solid mass of the ground, and the violent agitation of the liquid parts. A passing earthquake is known by a peculiar vibration, or rather undulation of the solid ground, which tends to throw down unstable bodies, and to communicate vertical or oblique impulses to all. It is not properly a vibration, but a forcible *rolling* of the solid crust of the globe once, twice, or several times. In some instances the effects are permanently indicated by opened fissures, subsided grounds, drained wells, elevated lines of country; but more frequently the yawning ground closes again, and the convulsion passes on. It has been observed that the apparent direction of the disturbance is the same in the same earthquake; that the celerity of the movement is very great, but not instantaneous, and, in some instances,

particular lines of country are found to be more commonly affected than others.

It has been found that perhaps the greatest effects of earthquakes happen on the sea-coast (Lisbon, 1755; Port-Royal, 1692; Catania, 1693); that the shock is felt in the sea as well as upon the land, vessels being struck upward by a heavy blow, which could not be by *vibration*, and waves retiring and reflowing at immense distances of coast from the places of principal disturbance.

From all the circumstances, it is apparent that earthquakes are the effect of a powerful mechanical force, accumulated to a maximum at particular points, and along certain lines, at a considerable depth below the surface. The rolling motion of the ground is a real undulation of the flexible crust of the globe, consequent upon fluctuations of an interior fluid, liquid or gaseous, which is very extensively spread below the solid rocks, and liable to irregular disturbances, which are, at least partially, relieved by volcanic eruptions.

On looking carefully at the recorded permanent effects of earthquakes, we find reason to believe that the most considerable displacements of parts of the land have been productive of local depression,—that, as the most frequent result, the land has sunk. It was so at Port-Royal in 1692; at Lisbon in 1755; at Caraccas in 1812. We read of Mount Acraus falling into the sea in 876; of Pompeiopolis being half swallowed up in 541; of Grecian cities overwhelmed in the deep; at Darlington ground fell in 1179; at West Ham in Kent in 1596; near Bordeaux in 1660.

But cases of at least temporary rise of the land also occur. In 1556, on the west coast of South America vessels were left dry far from their ancient place of mooring. In 1110,

the Trent was dry at Nottingham for a whole day; in 1158, the Thames was dry at London. According to Mrs Graham, the coast of Chili, for the distance of 100 miles, rose to a height of three or four feet above its ordinary level, indications appearing that many such accidents had happened before: this case has been the subject of much discussion. Permanent subsidences and elevations happened in the valley of the Indus in 1809.

Upon the whole, the frightful devastations ascribed to earthquakes are confined to particular regions of the globe, not far removed from the sites where volcanoes now are, or formerly were, in extreme activity. The permanent changes of level which they have produced in the last 1800 years, are very slight and difficult to substantiate. From 1048 to 1800 (752 years), no less than forty-five earthquakes were recorded in England alone; and no doubt many were unobserved; yet what remarkable permanent effects were ascribed to them even by the credulous chroniclers of the middle ages? After exploring all the exaggerated descriptions of the phenomena, written in the midst of fear and alarm, we rise from the perusal, satisfied that the effects of earthquakes are of the same kind as those performed by ancient convulsive movements of the globe, and similarly connected with variations of interior heat, but immeasurably inferior in amount. If modern earthquakes and volcanic fires be proportioned to the modern rate of variation of interior temperature, how much greater must have been the variations of heat corresponding to the incomparably greater convulsions of ancient date? It may be said, perhaps, that our period of 2000 years' experience is nothing to the long series of geological ages consumed in the production of these greater ef-

fects; it may be said, that such extensive displacements, whether effected by few convulsive movements, or many smaller disturbances, are equally a function of the time elapsed; but, surely, if we find the modern feeble earthquake and volcanic fire adequate to restore momentarily the equilibrium of the disturbed interior forces, they are the measure of such disturbances.

There may indeed be a residual phenomenon; the equilibrium may be only partially restored, and the uncompensated portions may be terms of a series continually augmenting, till it be satisfied by a great convulsion; this may be: but if so, the point is at once conceded; the inefficacy of earthquakes in producing such effects as the permanent uplifting of a mountain chain is granted, and for such an effect we must look to some other and more adequate cause than mere volcanic excitement. What, then, is volcanic excitement?

HYPOTHESES OF VOLCANIC ACTION.

Discarding the antiquated notion of volcanic phenomena depending on the combustion of coal-beds, the decomposition of sulphuretted metals, &c., we have only two hypotheses of volcanic action to consider. The authors of these speculations call them *theories;* but if we recollect how very insufficiently the laws of volcanic action have been developed, we shall not readily grant that any great progress has been made in developing the laws of causation; till this is done there is no true theory.

The hypothesis proposed by Cordier, of a heated interior mass mechanically disturbed, has been improved by the additional postulate, that the heated interior of the globe is chemically disturbed by access of water and other causes,

and in this state is in harmony with the general view of Leibnitz concerning the changing conditions of the globe, and with the course of partial inferences contained in the preceding pages. But these views and inferences must be further examined and more fully admitted before any hypothesis grounded on them can be adopted by more than a party in geology. This examination we shall briefly attempt hereafter, but, at present, the truth of the doctrine of volcanic action being dependent on local thermal disturbances, must rest upon its power of explaining phenomena under the disadvantages of the want of knowing the laws of these phenomena.

Another hypothesis was proposed by Davy, and, for a time, partially adopted by several chemists. Seeing the remarkable ignition and other effects of strong chemical action consequent on the excessive attraction of the metallic bases of the alkalis for oxygen, it was easy to suppose these substances existing uncombined in the interior of the globe, to imagine the local addition of water, or other substances containing oxygen, and thus to account for the violent ignition, alkaline products, steam, convulsive movements, and other phenomena of volcanoes. Dr Daubeny, the most strenuous supporter of this view in our days, places it on its true basis, viz. the power which it possesses of explaining phenomena. Thus both the hypotheses refer themselves to one and the same test.

It is, perhaps, commonly imagined that these hypotheses exclude one another, but this is unnecessary. Though the globe be hot within, it may contain uncombined the metallic bases of the earths and alkalis. Though it be to them that volcanic phenomena are owing, their action would not be impeded by a high temperature of the subterranean region, but, on the contrary, exalted.

It is further remarkable, that the points of agreement are great. It is requisite, upon either view, that water be admitted to a hot mass, or to one capable of becoming so; that chemical processes happen, in which oxygen is absorbed, and hydrogen and other gases released. The sublimation of sulphur, salts, metals, &c. is just as intelligible one way as the other. The situation of volcanoes in islands, on sea-coasts, and generally near water, is a consequence of either hypothesis; the long duration of volcanic foci,—the intermission of their action,—the gradual extinction of some of them, are quite as easily understood the one way as the other. Wherein, then, do they really differ? Principally in the development under the bias of the respective partizans. The hypothesis of Dr Daubeny is chiefly directed to the explanation of the chemical products in the order of their succession, and, so far as the chemical questions are concerned, it appears to answer the conditions required. The other speculation has been found more powerful in explaining the great extent of the subterranean movements to which volcanic fires are but a local appendage; it is more satisfactory, when viewed in connexion with older pyrogenous rocks and older tremors of the globe. Thus the Mechanical theory, as Cordier's hypothesis has been termed, explains better the mechanical effects; the Chemical theory, as Dr Daubeny's speculation has been named, fits better to the chemical phenomena.

But as they do not exclude one another, as both *may be true*, why are they put in such determinate opposition? What the substances are which occur at the base of volcanoes, is to be found by chemical researches; in what state they are as to temperature, fluidity, density, &c. is the province of general physics to ascertain.

We may, therefore, very consistently agree with Cordier, Von Buch, and De Beaumont, in viewing the origin o volcanic fissures as a case of violent displacement of the crust of the globe, arising from change of the thermal state of an interior fluid nucleus, and in ascribing to this mechanical condition the great extent of earthquakes from the bases of volcanic regions, and yet adopt at least the principle of Dr Daubeny's hypothesis. If we were to adopt completely the opinions of this writer, we should have the following view of the series of chemical processes.

The interior parts of the globe, whether hot or cold, fluid or concrete, consist, at least in part, of the metallic bases of the alkalis and earths, and of some metals; to this water, generally sea-water, and atmospheric air find access through irregular and variable channels in the rocks. The consequence is oxidation of the alkaline metals, potassium and sodium, the earthy metals silicium, aluminum, &c., and iron and other ordinary metals; a large volume of hydrogen will thus be liberated from its aqueous combination with oxygen; the atmospheric air will also be decomposed, and its nitrogen set free; chlorine will be liberated from its combination with sodium; sulphur will be disengaged from various mineral combinations in the superior rocks. Then the oxygen will combine with sulphur to constitute sulphureous acid gas, and with hydrogen to form steam; the oxygen being consumed, hydrogen will unite with sulphur, and form sulphuretted hydrogen, and with nitrogen to form ammonia, which, neutralized by chlorine, becomes sal ammoniac.

Besides these, which may be called the primary chemical phenomena, there may be noticed secondary phenomena depending on the mere communication of heat to the

rocks above. Such are the extrication of carbonic acid gas from calcareous rocks, the sublimation of sulphur so as to permit its combination with oxygen, to form sulphurous acid gas, and with hydrogen to constitute sulphuretted hydrogen. These and other effects are equally necessary on either hypothesis, and must be supposed to continue long after the primary chemical phenomena have ceased; as indeed, in old volcanic tracts, we know to be the case. In fact, along lines of dislocation of far higher antiquity than any merely volcanic mountains, we find the same phenomena of hot springs, carbonic acid, nitrogen, sulphuretted hydrogen, &c., and it thus appears almost a necessary consequence, that the heat, below a given point of the earth's surface, though no proper volcanic phenomena be there visible, is almost inexhaustible. Should not these considerations have weight in determining geologists not to refuse either the general thermal, or the local chemical hypothesis of volcanoes? Both are perhaps true, though we may not have the power of explaining by them all the yet imperfectly known phenomena, depending on the changing temperature and chemical conditions of the subterranean regions.

STATE OF GEOLOGICAL THEORY.

The caution which has been infused into every branch of natural science has been productive of excellent fruits in geology. Within a hundred years its whole aspect has been changed; from a mass of crude speculations fitted to inaccurate observations, it has gradually grown up to a system of sound, though limited, inferences, connected by

some very probable generalizations, and supported by independent mathematical reasoning. The *Laws* of *Phenomena* are unfolded to a considerable extent, and, in the opinion of eminent men of science, the time is at hand for effectual researches into the *laws of causation*. Not that the labours of observation should, for an instant, be suspended; *they* are the most important of all the means of advancing geology: on the contrary, they ought to be continually excited by new impulses, and turned into more profitable directions by the first, however rude, indications of theory. The state of geology is so prosperous, that its numerous cultivators may well agree to divide their forces so as to accomplish combined movements; to advance on the one hand the mass of generalized phenomena, and on the other to multiply the points of contact between dynamical, chemical, and vital laws, and the results of geological inquiry.

In the exhibition of this subject, it is almost singular how useless and even trifling a thing it is to refer to the ancient opinions on the constitution and changes of the globe, which modern sceptics concerning the progress of geology seem to have ever before their eyes as spectra, warning them of the danger of listening to the reasoning of the mathematician, the astronomer, the chemist, or the zoologist, when applied to the history of the globe. Were it not for this salutary terror which they inspire even in bold minds, the reveries of Whiston, Catcott, and Whitehurst, perhaps we may add of Werner and Hutton, as to the origin and changes of the globe, would be speedily forgotten. Even the beautiful work of Playfair loses its importance when fairly poised against the growing mass of partial geological truths; and perhaps we ought to look upon the hypotheses

of Von Buch, De Beaumont, and Lyell, as *over generalizations*, proper to excite and direct inquiry on particular points, and thus likely to have a temporary use rather than a permanent influence. However this may be, it is certain that the researches of the last fifty years have justified the words of Herschel: they have brought the grand problem of the history of the globe fairly within the circle of inductive science, linked it inseparably with the progress of physical science and natural history, so that its progress or retardation can only be proportioned to that of the general mass of human knowledge.

From this an important conclusion results: the close union and strict dependence of geological reasoning on the advancement of other sciences, must place a strong restraint on the presumption and confidence with which crude hypotheses have been often advanced by men of mere observation; in future it will be trusted to minds of a higher order, habitually exercised in the combination of natural laws, to propose leading views in geology. It is already known that a mathematical basis exists for geology as well as for astronomy, and the search for this cannot long be unsuccessful in the accurate hands of the analysts of France, Germany, and Cambridge.

So rapid is their progress that, even while we write, a large accession of knowledge is brought by Mr Hopkins, in a memoir on Physical Geology, presented to the Cambridge Philosophical Society, on the hitherto obscure subject of subterranean movements, and other investigations concerning the interior of the globe are opening upon us. The following view of the state of theory on several fundamental points cannot therefore be complete, perhaps not even free from inaccuracy.

Though inferences from geological phenomena, and deductions from assumed first principles in theory, may be almost infinitely varied, according to the extent of the data or the generality of the principles; yet, in fact, all theoretical views in geology, which can be considered general, are reduced to two types; the deductive speculations of Leibnitz, and the inductive hypotheses of Hutton. These are really and necessarily different, and whoever ventures to choose one or other of these great leaders, must in effect decide for himself the following important question:—

Are the disturbances of the statical condition of the terrestrial forces of organic and inorganic nature of a periodical character merely, so that in any sufficiently long period embracing all the cycles of their variations, the sum of their effects is equal to the sum of a corresponding earlier or later period, which is Dr Hutton's view put to extreme; or, are these disturbances of the nature of a series whose successive terms, (whether a single disturbance or cycles of periodical disturbances), differ from one another in any regular progression? (as Leibnitz supposes.)

This question cannot be answered upon analogy merely. Though the planetary system exhibits in all its perturbations a character of variation, such that the sum of the movements taken in any sufficiently long period is found to be constant, and the whole system permanent, unless the extraneous influence of the ether tend to slowly alter its condition, we cannot deduce that the parts of this system shall, *in matters of another kind*, have the like character of circular perpetuity. Nor, on the other hand, because of the many proofs of great convulsions in ancient periods, and of the rarity or even absence of such phenomena

in historical times, may we conclude that such convulsions will never be repeated. There may be a periodicity of these great disturbances of the solid globe, as we know there is of the lesser irregularities of the atmosphere surrounding it.

This great question is then to be tried by the applicability of one or other of the leading principles which it involves to the explanation of the phenomena of all geological periods, and the only thing remaining to be settled is the degree of preparation in which we find ourselves for such a trial of principles.

Have we data, or laws of phenomena, sufficiently certain and known in all their relations to allow of ascending by inferences to one of the rival principles, or of testing deductions from the other?

It is probable that we have not such knowledge. For neither do we know fully the present state of operation of terrestrial forces, including, of course, their submarine effects, nor their condition at any one former period; and it is only by a rigorous and careful scrutiny, and comparison of many different periods, that any just determination can be formed as to the laws which regulate the variation of the forces. The utmost, then, which can be expected is a presumption in favour of one or the other theoretical principle, according to its observed correspondence with the succession of phenomena which are best known.

Even this task we shall not attempt. Instead of it we shall employ a particular consideration really common to both of them, though in their development under the hands of partizans, it has come to be almost exclusively associated with the Leibnitzian speculation. Either of the principles previously contrasted admits of being developed

in two modes; according to both of them the changes now going on upon the globe may be part of a long series of similar or gradually changing phenomena, never interrupted in their operations by extraordinary exertions of the same or different forces. This is Mr Lyell's doctrine; or the present may be viewed as a period of ordinary action of terrestrial forces, similar to many which have gone before, and which have been preceded and terminated by greater and more violent effects of intermitting agencies. (This is the view of M. De Beaumont.)

It is certain that unless this limited question can be disposed of the general principles cannot be properly examined, and in the discussion of even this really practicable problem all the knowledge yet gathered in geology may perhaps be found inadequate. It will, however, be useful to make the attempt, if only for the purpose of pointing out the lines of research on which geological observation may be profitably directed.

In the system of continual compensation among the agencies of terrestrial nature, deluges and convulsions, greater than those of the modern period, have, strictly speaking, no place; or if we relax a little the rigidness of the dogma, and allow that, by a fortuitous combination of circumstances, greater movements and inundations may have happened than have been recorded in the last thousand years or so, at least these must be shewn to be perfectly consistent with the ordinary diurnal measure of the influential agencies. For example, a lake may be slowly emptied by erosion or suddenly by an earthquake; the effects are very different; but the agencies equally belong to the present system of nature. Great effects may thus be performed, in consequence of particular combina-

tions, by very moderate measures of force; but in applying this system to older phenomena, we must examine the *direct effects*: convulsionary movements must be the measure of disturbing forces, and diluvial effects the guide to inferences concerning cataclymal agencies.

ORIGIN OF THE MATERIALS IN THE CRUST OF THE GLOBE.

The compound nature of these materials is a subject of great interest in any theory of the changes of the globe. When we consider the various minerals included in one rock, as granite; the definite chemical formula which represents the attractive forces of each of these; the molecular and elementary constitution of the different parts of each; and recollect that any one of these molecules and elements has various physical properties, how improbable does it appear that we shall ever arrive at a knowledge of the changes of condition through which these unchanging particles have passed! Yet it is almost impossible to avoid the endeavour, useless though it be, to separate these particles in imagination, and to represent them to the mind in a state of individual, though associated existence.

This is what Laplace and Herschel have expressed when they presented, as the result of their profound reflections, the speculation of this globe originating from the condensation of a gaseous expansion in space—a notion often extended to the other planets, and supposed to be in harmony with the common direction of their motion round the sun, the nearly coincident planes of their orbits, and other less striking circumstances. That such gaseous or vaporous expansions exist in space is known both by observation of comets, and of nebulæ.

Perhaps this view, as it is certainly the most elevated, is also the most correct hypothesis of the early formation of the globe; but it would be unfair to employ so speculative an argument against the doctrine of continual compensation among the agencies of Nature, because this was proposed only for the terraqueous globe. Given, then, the globe reduced from its gaseous expansion, we may proceed to inquire into the proximate origin of its ancient rocks Here a real discordance arises between the two systems compared. While describing the primary strata, we have shewn the grounds for believing them to be derivative aqueous from primitive igneous rocks; but Mr Lyell, in his ingenious development of the Huttonian philosophy adds to this a reverse proceeding. According to his view the sedimentary aggregates from water at the surface of the globe, are derived from other such rocks, or from pyrogenous products; but whatever was their proximate origin, they change again in the deeper parts of the earth, by gradual transformation into crystalline or igneous rocks. So that the mechanical agency of water above, and the transforming agency of heat below, are, in this hypothesis, antagonist forces, separated by a zone of rocks (the crust of the earth, as it is technically called) which above are of the aqueous, but below of the igneous kingdom.

Between these two polarities, so to speak, the particles of the exterior parts of the earth continually circulate. Fire raises matter from below: water wears away the high parts of the surface, and adds to that load of strata which in the lower part is hourly changing to granitic and other crystalline rocks, "equal quantities in equal times."

In support of this view, only local and limited facts can be adduced; but these, as far as they go, are important.

It is found that earthy limestones, such as commonly occur in secondary strata, are converted, by heat and proximity to pyrogenous rocks, into crystalline marble, such as occurs in primary strata (Kaiserstuhl, Teesdale, Antrim); that lias shales assume the aspect of clay-slate (Vale of Chamouni) near the primary rocks; that common sandstone becomes quartz-rock under the influence of heat (Caer Caradoc). Hence, as a consequence, we infer the consolidation, and many other characters of primary strata, to be the effect of heat. But this falls short of the proof required, which must be to the extent of shewing, not the changes of secondary to primary strata, but the changes of these into granite, and other crystalline rocks generally. Satisfactory proof of this nature and to this extent, is, we believe, nowhere afforded.

Moreover, what has been said before of the character and origin of the primary strata, their relation to the development of organic life, and other circumstances, appears sufficient to shew that their formation is, in some important respects, of a different kind from that of secondary sedimentary rocks; that the influencing conditions as to heat and watery agency were dissimilar; that the globe was then really in a different state generally. If so, we must certainly reject the doctrine of continual uniformity of natural operations, and admit alternating periods of different modes and measures of mechanical and chemical action. It is probable, then, that the successive systems of strata which have been described, are all that have been formed above the original crystalline rocks by the operations of water.

ORIGIN OF CONVULSIVE MOVEMENTS OF THE CRUST OF THE GLOBE.

Periods of Occurrence.—The proofs of the occurrence of such have already been given. Many examples have also

been presented. It remains to ascertain what progress has been made towards discovering the cause.

It is certain that convulsive movements have happened at various periods during the deposition of the strata; and, notwithstanding the difficulties noticed in an earlier part of this essay, as to the determining of their exact geological date, there is already collected a great mass of information on the subject. One of the most important results yet arrived at, is the conviction that the time occupied in these convulsions was very short, compared to that which was consumed in the deposition of the strata; short periods of convulsion alternated with long periods of ordinary action. This at once decides the question as to the uniformity of the effects of natural agencies in the negative. It is also found that the effects of these convulsions were very extensive. The exact contemporaneity of those which followed the Plynlymmon rocks of Cumberland, and the slaty rocks of North Wales and Cornwall, may not be proved, and is not, for this part of the subject, very important. They happened within a comparatively short period, so as to shew that the spasmodic action was extensively felt within certain limits of geological chronology, in quarters where it had not been experienced before; and the general unconformity of stratification between the primary and secondary strata, shews that an almost universal disturbance or series of disturbances happened within these limits.

Magnitude of Disturbance.—The extent of the dislocations effected by particular convulsions is really enormous, and puts to shame the utmost exertion of a succession of modern earthquakes for many thousands of years. The Penine region of the north of England, elevated posterior to the era of coal-measures, is defined on three sides by dislocations of 1000, 2000, 3000, and more feet; and there

is, perhaps, as little reason to suppose that more than one effort was employed on any one of these sides, as in the case of an ordinary fault. Such faults, indeed, sometimes occasion depression of several hundred feet; but seldom for such great lengths as the Penine and Craven disturbances.

It is not easy, nor perhaps possible, to prove that single efforts have raised the Grampian or Snowdonian chains to their present elevations; yet, in many cases, it is hardly to be supposed that more than one exertion of force has been applied to straight anticlinal axes like those of the Malvern Hills, the Caradoc Hills, the Ribblesdale Ridges, and others of considerable extent.

Systems of Disturbance.—From careful inquiries it is found possible to range the disturbances into systems related to geological time, so as to present proofs of a definite number of considerable convulsions having visited a particular region. Thus, in the British Isles, the following systems of disturbance occur in the particular periods mentioned.

First Great System.—After the deposition of the Cambrian slates. The Grampians and Lammermuir; the ranges of Donegal and Cavan; the Cumbrian Mountains; Snowdonia; the Ocrynian Chain of Devon and Cornwall; are supposed to have been uplifted at this time.

Second Great System.—After the deposition of the coal-measures. The greater number of dislocations in the coal-fields of Great Britain; the great Penine Fault, Craven Fault, and Ribblesdale Anticlinals; the Derbyshire Faults; those of Mendip, South Wales, were then produced.

Third System.—After the deposition of some parts of the New Red Sandstone strata. The Tynedale Fault; Faults in the coal-fields of Shropshire and Dudley; on the northern border of Derbyshire; the ridge prolonged from the Breiddin Hills.

Fourth System—After the Oolitic period. In Yorkshire and Dorsetshire.

Fifth System—After the Marine Tertiaries of the South of England, Isle of Wight, &c.

On turning to the continent of Europe, we find that M. De Beaumont, besides recognising these five systems, proposes several others, amounting in all to twelve; but we shall only add the two which have affected the Alps in periods probably later than any of those of the British convulsions.

The System of the Western Alps, which appears to have followed upon the deposition of tertiary strata of the age of the Touraine beds (Meiocene, Lyell).

The System of the Eastern Alps, parallel to the vale of the Danube. Some supratertiary or diluvial beds are stated to be disturbed by this convulsion.

M. De Beaumont suggests that the elevation of the Andes may have been posterior to all these; and a curious though inexact corroboration of this opinion has been lately furnished by Mr Darwin, who finds, in the southern parts of the chain, strata of extremely modern date uplifted to the height of several thousand feet.

In North America there appears, according to Professor Rogers, reason to suppose that, since the disturbances of the primary and carboniferous strata, the whole secondary and tertiary periods of geology have left few traces of any important convulsive movements.

Direction of Convulsive Movements.—The first notions on this subject were formed by miners, who in the course of their experience observed, as a fact of great practical importance to their art, that the mineral veins which were most generally and uniformly productive ranged east and west, or nearly; and that these *right running* veins were divided by *cross-courses*, passing north and south, or nearly. Not that there are no other directions of veins and cross-courses, but, amidst many directions, these prevail. Cornwall, Wales, Cumberland, the Penine limestone region, Brittany, the Harz, the Hungarian mines, and even Mexico, appear to confirm this law suggested by practical men. It is very difficult, or rather impossible, to explain it; but we may remark, that, in many cases, the direction of mineral veins follows that of the natural joints and fissures produced by consolidation of the rocks; and that it is very conceivable that electrical currents, or other polarizing agents, might communicate to such fissures one or more definite directions. In fact, it is proved that in Yorkshire, Derbyshire, and other large tracts, these fissures have definite directions, mostly rectangular to one another.

But it is to M. De Beaumont that we owe the proposal of the direction of convulsive movements, as a new and important problem in geology. He supposes that disturbances of the same system or geological era are parallel to a certain great circle of the sphere; that those of different periods are related to different circles, the poles of these circular systems being very irregularly posited on the globe. There are facts which make for and against this hypothesis, but it is difficult, in the present state of our knowledge, to come to a right conclusion on the matter. It is very difficult to know the relative ages of *distant* convulsions, be-

cause the lines of contemporaneous stratification are often entirely unknown. Adjacent convulsions, even if parallel, cannot prove a rule which is to apply to a whole circle; moreover, local variations of a line of convulsion sometimes derange all the reasoning.

Instances in favour of the view of M. de Beaumont may be found in the British islands,—none more remarkable than the north-east and south-west axes of anticlinal elevation, which compose the first great British system of disturbed strata. Less extensive analogy obtains among the many anticlinals of Ribblesdale, which belongs to the second system; but this also ranges north-east and south-west, or east-north-east and west-south-west; while of other lines of the same date in the same region, one, the Penine Fault, ranges north-north-east, and north-north-west; another, the Craven Fault, ranges west-north-west. If the South Wales system be contemporaneous (and it has not been proved to be otherwise), east and west directions must be added to these various lines; and what makes the whole more perplexing, is the recurrence of east and west directions in the post-tertiary, or fifth English system, between the basins of Hampshire and London.

Under these circumstances, it is clearly impossible to adopt De Beaumont's hypothesis, for want of evidence either exact or extensive enough to substantiate it. But yet entirely to reject the principle which it involves, would be not only rash, but positively contradictory to important facts. That some symmetrical accordance does really exist, and is traceable between the dislocations of a particular age in a particular region, is certain. Some cases are known of this symmetry being more extensively recognised. We may therefore continue our inquiries, not to test the

hypothesis of De Beaumont, but to find out what is the truth.

Results of Observation.—In Mr Murchison's notices of the silurian system, and the igneous rocks associated therewith, are many proofs of the local parallelism of ridges of trap, and anticlinal axes in these ancient rocks, combined with some general directions of dislocation. The prevailing strike of all these deposits is north-east and south-west, or parallel to the Snowdonian chain, from Shropshire to the mouth of the Towey, a range of 100 miles. Within this space are numerous minor axes of dislocation, short, but parallel to the same great strike of the beds; the beds dipping north-west and south-east, from ridges of trap. This general line of dislocation is broken through by transverse rents and fissures. A north-eastern strike belongs to the Ludlow rocks and the old red sandstone. On the eastern side of the red sandstone of Herefordshire, the ridges of Abberley and Malvern point north and south, but are complicated by minor ridges running in different directions. They are posterior to the coal formation.[1]

In the mountain limestone tracts of Yorkshire, the dislocations present the following general characters:—The faults and mineral veins have a tendency to range at right angles to one another; the lesser faults and veins terminate in the greater to which they are rectangular. Where the great or Penine fault changes its direction, the veins also change. The intersection of the branches of the Penine fault with the main stem, though one of these branches is not of the same age, is nearly perpendicular. In the Ribblesdale system of anticlinals, many parallel ridges east-north-east and west-south-west occur, and these

[1] *Geological Proceedings.*

are subject to very frequent cross-rolls or undulations, which break them into oval quaquâversal elevations. Mineral veins tend to cross these axes (one goes along an axis.) The Ribblesdale anticlinals are directed at right angles toward the Craven fault, and near this fault some of them bend and turn to coincide in its direction. "If we conceive all the country south of that fault to have undergone a vast relative depression, and that at right angles to the line of the fault many parallel undulations sprung out, which arrived at their maximum of curvature a short distance from the fault, we shall have a right notion of the case." [1]

Results of Mathematical Inquiry. It is evident that the preceding results of observation, coupled with the experience of miners and many other circumstances, point to some common principle, which must recognise as one of its results, a tendency to local parallelism and rectangulation among the lines of dislocation in a given region. A valuable contribution for this object has lately been added to geology by Mr Hopkins (*Camb. Trans.*), who, from very simple and probable assumed conditions of the crust of the globe, has deduced mathematically a series of dynamical results for comparison with the observed laws of phenomena. The following extract will explain his views and methods of inquiry:—" The hypotheses from which I set out, with respect to the action of the elevatory force, are, I conceive, as simple as the nature of the subject can admit of. I assume this force to act under portions of the earth's crust of considerable extent, at any assignable depth, either with uniform intensity at every point, or in some cases with a somewhat greater intensity at particular points; as for instance, at points along the line of maximum elevation of an

[1] *Geology of Yorkshire*, vol. ii. p. 119.

elevated range, or at other points where the actual phenomena seem to indicate a more than ordinary energy of this subterranean action. I suppose this elevatory force, whatever may be its origin, to act upon the lower surface of the uplifted mass, through the medium of some fluid, which may be conceived to be an elastic vapour, or, in other cases, a mass of matter in a state of fusion from heat. Every geologist, I conceive, who admits the action of elevatory forces at all, will be disposed to admit the legitimacy of these assumptions.

"The first effect of an elevatory force, will of course be to raise the mass under which it acts, and to place it in a state of extension, and consequently of tension. The increase of intensity in the elevatory force, might be so rapid as to give it the character of an impulsive force, in which case it would be impossible to calculate the dislocating effects of it. This intensity and that of the consequent tension, will therefore be always assumed to increase continuously, till the tension becomes sufficient to rupture the mass, thus producing fissures and dislocations, the nature and position of which it will be the first object of our investigation to determine. These will depend partly on the elevatory forces, and partly on the resistance opposed to its action by the cohesive power of the mass. Our hypotheses respecting the constitution of the elevated masses, are by no means restricted to that of perfect homogeneity; on the contrary, it will be seen that its cohesive power may vary, in general, according to any continuous law; and moreover, that this power, in descending along any vertical line, may vary according to any discontinuous law; so that the truth of our general results will be independent, for example, of any want of cohesion between contiguous hori-

zontal beds of a stratified portion of the mass. Vertical or nearly vertical planes, however, along which the cohesion is much less than in the mass immediately on either side of them, may produce considerable modifications in the phenomena resulting from the action of an elevatory force. The existence of joints, for instance, or planes of cleavage, in the elevated mass, supposing the regularly jointed or slaty structure to prevail in it previously to its elevation, might affect in a most important degree the character of these phenomena. To a mass thus constituted, these investigations must not be considered as generally applicable."[1]

After a very clear summary of the mathematical results of the investigation, first as to a thin lamina acted on by one, two, or more systems of tensions, and, finally, to a mass of three dimensions, the author proceeds to apply these results to the actual case of a portion of the earth's crust, under the hypotheses respecting the action of the elevatory forces, and the cohesive power of the mass, which have been already stated.

1. *Longitudinal Fissures.* In the case of a mass of indefinite length, bounded laterally by two parallel lines, with the elevatory force uniform, the extension, and therefore the tension, will be entirely in a direction perpendicular to the length, so that its whole tendency will be to produce *longitudinal* fissures, or such as are *parallel to the axis of elevation.* These fissures will not commence at the surface, but at some lower part of the mass. The whole series of stratified rocks existing above an originating line of fissure, will be affected by the tension producing it; but under certain cases the fissures may not reach the surface.

[1] *Cambridge Trans.* 1835.

The width of the fissure will be nearly the same at all depths of disturbed strata (varying, however, with their elasticity). Any number of these fissures might be formed simultaneously, more, it is probable, in the deeper parts. Thus there are complete and incomplete fissures, all parallel to the axis of the uplifted tract.

2. *Transverse Fissures.* If the elevatory force be supposed to act with greater intensity at particular points along the general line of elevation, or an additional force *superimposed* on a uniform force, the axis of elevation will be undulated by one or more cross ridges and hollows; and parallel to these another system or systems of fissures may be produced, circumstanced like the longitudinal fissures previously mentioned, as to completeness, width, &c. but ranging across *the axis of elevation* and approximately perpendicular to the longitudinal fissures. This result is almost independent of time: the transverse fissures may be instantaneously following, or very long subsequent to the longitudinal fissures.[1]

3. *Fissures of a Conical Elevation*, if produced solely by forces of great intensity and limited area, will commence along or very near to the axis of the cone, and be continued in a vertical plane, passing through the axis. If such forces were exerted *simultaneously* with those determining a general axis of elevation and fissures parallel thereto, the result would be a local convergence of such longitudinal fissures towards the axis of the conical elevation, beyond which they would resume their parallels. A contrary deviation of these fissures would follow upon a spherical elevation.

[1] These deductions from theory are supported by many well established facts.

4. *Faults.* By the decrease of the expansive forces which produced the tensions occasioning the fissures, the equilibrium of the divided parts would be destroyed, and they might rest in unequal elevation above their original level, thus producing longitudinal and transverse faults. Anticlinal, synclinal, and simple faults, are thus easily understood to be all consequences of the new positions taken by the divided rocks upon the cessation of the sustaining forces.

Without prosecuting further our abstract from Mr Hopkins' ingenious paper (which embraces, however, many other remarkable coincidences with observations), we may quote his important conclusion.

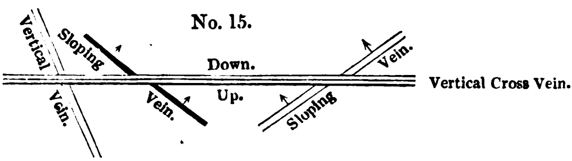
"If the approximate accuracy of our assumptions be allowed, as applied to the crust of the globe, it appears from our investigations that an elevated range characterized by continuous systems of longitudinal and transverse fissures, referrible to the causes to which we have been assigning such phenomena, could not be produced by successive elevations of different points, by the partial action of an elevatory force. In such elevations, fissures would necessarily diverge in all directions from the central points, so that parallel systems, such as have been mentioned above, could not possibly be thus produced. Every system of parallel fissures in which no two consecutive fissures are remote from each other, must necessarily have had one simultaneous origin."

ORIGIN OF MINERAL VEINS.

This has long been, and will for some time continue, a disputable question in geology; but considerable progress has been made in it since the days of Werner and Playfair.

The origin of the fissures in which a great proportion of mineral veins occur, is certainly proved to be either by molecular attraction, causing contraction of the mass of rock, and thus generating joints or divisional planes, or by the tension of elevatory forces, as explained in the last section. *The relative antiquity* of the fissures constituting rake veins, (in Cornwall called lodes), is become a practicable problem, since Mr Hopkins has given mathematical deductions to aid the observation of facts. When, as is universally found in a mining district, some veins as A B cross others as C D, (Diagram No. 15.) and interrupt them, the conclusions of

No. 15.



the miners have generally been in accordance with the Wernerian dictum, viz. that the continuous vein is of less antiquity than that which it divides; but Mr Hopkins thinks this conclusion untenable. For if the displacements of the veins be only apparent, that is, if either of the fissures has been originally formed with the irregularity in question, in consequence of any line of least resistance affecting the direction, it must be the newer C D, which has deviated along the fissure A B, and then resumed its bearing.

But if the displacement be real (whether vertically or horizontally), then, as far as relates to the fissures, they may be contemporaneous. It may, however, be possible from other considerations, to determine the relative epochs of the introduction of mineral matter into fissures, if not the geological dates of their production.

The differences of the contents of veins in a given mining region, *e.g.* Cornwall, appear certainly in a considerable degree related to their directions. Werner long since proposed a classification of veins founded on their directions and contents, and supposed it possible to refer even English mineral veins to their place in his Saxon Mining System from such considerations. (Werner on Veins, translated by Anderson.) Mr Carne gives no less than eight principal systems and ages of mineral veins in Cornwall. The criteria of age are founded on the displacements of the veins; east and west is the most prevalent line of productive veins; north and south of the cross courses, which are generally unproductive.

Repletion of Mineral Veins.—The opinion of the Cornish miners and geologists generally appears to be, that most or all of these veins are to be regarded as contemporaneous with the rocks which enclose them; but the arguments for this contemporaneity are not so satisfactory as those employed by Professor Jameson in the case of contemporaneous veins in igneous rocks.—*Wern. Trans.* Dr Boase and others, however, mention the change of metallic contents with change of rock,—the favourable or unfavourable character of certain rocks for yielding ore, &c.

Whatever force may be thought due to the facts and the opinions brought forward on the subject of veins in Cornwall, it is perfectly certain that, in distinctly stratified countries, the mineral matter has been introduced into open fissures long after the deposition and consolidation of the strata. *The proof is unanswerable.* Joints and fissures filled with metallic and sparry matters (mineral veins), pass through rocks which are not contemporaneous but successively deposited, and *divide corals, fishes, &c.*[1] It is evi-

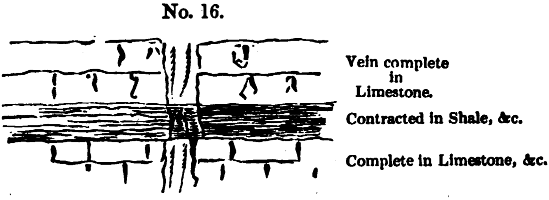
[1] *Report British Association*, Edinburgh Meeting.

dent that this must close the discussion as far as regards these rocks.

But, though it cannot be reasonably doubted, as a general truth, that the vein-stuff has been transferred into open fissures of the rocks, it is not so easy to determine how this was effected. Have the materials been injected from below as lavas into the fissures of a mountain (Hutton), or sublimed from a hot region to a cold fissure (Buckland), or segregated by some peculiar influence from the neighbouring rocks (Sedgwick), or poured into them in aqueous solution (Werner), or transferred by electrical currents (Fox), as in some instances we have good reason to believe?

In the present state of our knowledge neither of these results can be admitted exclusively, yet perhaps none ought to be absolutely rejected as a cause of the repletion of metalliferous fissures. Many veins appear as much the result of a real injection of sparry and metallic matters from a subterranean source as any rock-dykes or granite-veins. But when, as in Derbyshire, we find mineral veins divided horizontally by a particular stratiform mass, as toadstone, and in other parts by argillaceous beds, so that the vein, being a full fissure above and below, is only represented in the toadstone or shale by one or a few strings of calcareous spar, it becomes evident that injection is not the only cause of the repletion of mineral veins. See Diagram No. 16.

No. 16.



Sublimation from the heated subterranean laboratory of nature through the fissures of rocks is a very probable, but not universal, cause of the repletion of veins. It is probable because of the agreement between the successive vertical lamination of the materials of a vein and the supposed successive introduction of them to the fissures; but this is not conclusive, inasmuch as the processes of crystallization from a general fluid mass may as well be appealed to for producing the same phenomenon. It is not universal, because of the frequent occurrence of perfectly insulated nests of metallic and sparry matter in shells and in the substance of rocks. These, indeed, afford a very strong *prima facie* argument in favour of the collection by molecular segregation or electrical transfer of the different particles. If we consult general probability, it will appear most reasonable to admit these separate aggregations of metallic and sparry matter, as being laterally transferred *from the vein* rather than examples of *segregation from the rock*. Nearly every case of peculiar apparent relation between the sparry and metallic contents of a vein to the nature of the enclosing rock, vanishes on a careful scrutiny. It is not because of any peculiar chemical quality that limestone yields most lead-ore in Aldstone Moor, but because of its being a rock which has retained openness of fissure. Gritstones, in many mining fields near Aldstone Moor, are equally productive; but shales, as being soft extensible layers, have closed up the fissures, and their crumbling faces appear to have rejected the crystallizations which attached to the harder limestone, gritstone, and chert.

If any doubt could remain on this point, it is removed by the observations of Necker, Dufrenoy, Murchison, and others, as to the real and evident dependence of mineral

districts, that is, districts where the rock fissures are full of valuable minerals, upon axes of disturbance and upliftings of igneous rocks. In the Pyrenees, in Brittany, in Cornwall, the Shelve district of Shropshire, Flintshire, Derbyshire, Yorkshire, Aldstone Moor, this important law is certain. Whatever be the chemical nature of the rock adjoining the dislocation or igneous rock, the productiveness of the veins is chiefly regulated by its condition as to fissures. Limestone in Derbyshire, millstone-grit in Nidderdale, chert in Swaledale, basalt in Teesdale, coal near Bradford, and Richmond, all yield sulphuret of lead and various associated sparry substances.

Prevalence of Mineral Veins in Rocks of different Age.—As a general result, we cannot doubt of the far greater prevalence of mineral veins in the older than in the newer rocks. Not one case is known of a mineral vein being at any time worked in any part of the British islands above the new red sandstone. In the new red sandstone and magnesian limestone hardly more than slight traces of such products occur; they are rare in our coal-tracts, but they become abundant in the mountain limestone and older strata. But yet it is probable that this relation of mineral veins to the age of deposits is merely a consequence of the more general truth, that their origin is from below, that the fissures which they occupy, and the metallic and sparry matters which compose them, are more numerous near the igneous rocks which in so many instances form the axes of movement. It is not merely because of the antiquity of the Killas of Cornwall, but of its proximity to granite rocks, that it is so very metalliferous; the limestone of Ireland, undisturbed by great axes of movement, is very little metalliferous; while the same rocks dislocated in Mendip,

Flintshire, Derbyshire, &c. yield many sorts of metals and spars, in veins of different kinds.

Thus, the most general point of view in which mineral veins present themselves, is that of dependence on proximity to the sources of subterranean heat. In the rocks nearest these sources they are most numerous and varied; they abound near the disturbances which are consequences of variation of internal heat; and, in certain cases, (Pyrenees, &c.), they are not rare even among newer strata where the subterranean igneous rocks have exerted a remarkable influence.

DESICCATION OF THE ANCIENT BED OF THE SEA.

The strata, with their organic contents, having been already proved to have formed in succession the bed of the sea, and the far greater part of the surface of the globe even to great heights in the Andes and Himalaya, the Alps, Pyrenees, Caucasus, and other mountains, it follows that nearly the whole terrestrial surface of the globe was formerly submerged, and has since been laid dry. The desiccation of the land is a problem of fundamental importance in geology, influencing a multitude of secondary inquiries. If we might venture to suppose the quantity of water upon the globe variable, the land might be imagined to have risen above the ocean in consequence of the great abstraction of the latter; but, in the first place, there appears no probability that such a supposition is admissible, even by bringing a comet in contact with the earth; nor does it agree with the observed condition of the strata. For these by no means appear in such arrangements as to correspond with what we know of the character of a large part of the stratified bed of the sea.

Dismissing, then, this notion, and restricting ourselves to the conditions of sensible constancy in the quantity of water upon the globe, we find the problem of the desiccation of the bed of the sea reduce itself to the determination of the causes of the change of relative level of land and water.

Such a change of relative level might happen in many ways, some with, others without, local changes in the form of the solid parts of the crust of the globe. To the last class may be referred variations of level arising from change of temperature or alteration of the earth's axis of rotation. The former includes a variety of cases of subterranean movements.

EFFECTS OF VARYING TEMPERATURE NEAR THE SURFACE OF THE GLOBE.

Whatever be the constitution of the interior of the globe, a general change of temperature of the whole mass of land and water must of necessity alter the relative level of land and sea, because the ratios of expansion and contraction of the solid and liquid parts are unequal. Water changes its dimensions in a higher ratio to the difference of temperature than the rocks of the crust of the globe; hence a general cooling of the mass of the globe, or to a considerable depth from the surface, ought to cause the *ocean to sink* relatively to the land; on the contrary, with any augmentation of temperature the *ocean would rise* upon the land. As sea-water contracts continually down to its freezing point, and the greater part of the ocean never freezes, we may, by assuming a probable mean depth, arrive at some useful results. If the mean depth of the ocean be taken at ten miles, which is probably too much, though nothing is

positively known, and it be supposed to have cooled from a boiling heat to a mean temperature of 40° F., its change of volume would be about $\frac{42}{1000}$. The corresponding cubical contraction of the land, supposing it to have the rate of expansion in glass, would be about $\frac{3}{1200}$. If the areas of the surfaces of land and sea were supposed nearly to continue in the same proportion, the whole cubical contraction of the land and water would operate in lowering their level 10 $\times \frac{42}{1000} - \frac{3}{1200} = 0{,}395$ miles, relative lowering of water-level. But this cannot be admitted; for the slopes of the land into the sea, over a great part of the globe, are very moderate. If the linear contraction of the water alone be taken, and compared with that of the land, we have the lowering of the ocean $= 10 \frac{42}{3000} - \frac{1}{1200} = 0{\cdot}132$ mile $= 697$ feet.

When we consider the gently sloping surfaces of a large part of the land, we shall see that the contraction of the area of the ocean would diminish its linear depression, and upon the whole we cannot doubt that a fall of 697 feet is much beyond the amount that could possibly happen if the whole ocean had cooled from a boiling temperature to 40° Fahr. But this difference of level is too small to account for the desiccation of more than a small portion of the surface of the land; the hypothesis must therefore be abandoned as a general explanation, though hereafter it may be found of great importance in a more comprehensive theory.

GENERAL CHANGE OF DIMENSIONS OF THE GLOBE.

Let us now trace the effects of a general change of the dimensions of the globe on the relative level of land and water.

If we suppose the whole globe to undergo change of di-

mensions by variation of heat, the effects already ascribed to variation of temperature in the exterior part would still take place; but, in addition, would be complicated with an effect depending on the change of spherical area of the surface. In the case of augmenting temperature of the whole globe, the water would rise upon the land, as explained in the last section, but its rise would be less in that case, in consequence of its expansion over a larger area. If the expansion of the whole globe should go to such an extent as to change the diameter (D) into D $\times$ ($\sqrt{1\cdot039}$), or from 7900 to 8055 miles, the fall of the ocean would equal the rise of it due to the unequal expansion of land and water from 40° to 212°.

It appears, then, that the desiccation of land is not an effect of the general cooling of the globe, *without change of form*, for the effect due to that is of a contrary description; nor of the unequal contraction by cooling of the superficial parts of the globe, for that effect, even through the whole range from boiling heat (212°) to 40° F. would be totally inadequate to account for the phenomenon, even if the depth of the ocean be supposed far greater than it is admitted by astronomers to be.

Of the great physical events to which such a change of level may be ascribed, sound reasoning excludes all that are exterior to our globe; none of its relations to the sun and planets, none of the changes of these relations, are of importance in the matter. The only leading event really influential on the point, which we may *imagine* possible, though astronomers give no encouragement whatever to the admission of it as a basis of speculation, is a change of the position of the earth's axis.

Upon the occurrence of such an event, there would evi-

dently be a new disposition of the ocean; its waters would flow from the new poles towards the new equator, and some ancient lands might thus be submerged, and extensive surfaces laid dry.

The actual polar circles ought to be land; the equatorial zone should be deep sea. This want of agreement is remarkable; and, when we add to it the consideration that the absolute fixity of the pole of rotation, in a spheroid of revolution such as the earth is known to be, is a point supposed to be proved, we shall feel the necessity of abandoning altogether the attempt to explain the desiccation of the land, by imagining general depression, or partial abstractions of the ocean, without local *changes of form of the surface of the globe.*

CHANGES OF FORM OF THE SURFACE OF THE GLOBE.

Admitting such changes, the partial abstraction of the ocean may be viewed as a natural consequence, and the surface of the land may be studied, for the purpose of discovering the points of depression and elevation. We are thus brought back again to the observation of local phenomena, and may proceed by induction.

It is undoubtedly certain, by a large induction of examples derived from various geological periods, that mountain ranges and tracts of plain country have been raised by local elevatory forces. Anticlinal axes, parallel and rectangulated faults, are of a nature to prove the truth of this view. By such means, large breadths of land have been influenced, near and at considerable breadths from the axis of elevation. It further appears that still larger tracts of land, where no such evidence of violent and convulsive disruption of the strata occurs, must be supposed to have been

gently and gradually lifted by an intumescence or expansion of the surface, depending on a continuous and very extensive subterranean agency. Thus, after the elevation of the Snowdonian chain, and the ridges of the silurian system,—after the Malvern and Abberley elevations,—the whole plain of the midland counties has experienced one general upward movement of a few hundred feet. Thus, the ancient vale of Eden has been raised since the rising of the Penine chain; and with it the whole area of the red sandstone round the Solway Frith, after the relative uplifting of the Lammermuir Hills. Instances of this double movement in the same physical region are almost universal.

That the elevation of the crust of the globe in one part was accompanied by depression in other parts, is extremely probable; but we cannot offer satisfactory proof from observation of more than local subsidences, and these generally complicated with subsequent elevations. The best case of such fluctuations known, is perhaps that of the emersion, submersion, and re-emersion of the Portland oolites, as indicated by the dirt-beds.

It is, of course, in the sea that we are to look for effects of subsidences, as the land gives those of elevation. To whatever extent we suppose such subsidences to have happened, and the level of the sea to have been thereby lowered, the phenomena indicative of a real elevation of the land are not less conclusive. This is a matter of calculation.

From Mr Hopkins's researches, it appears that the elevatory agency was of the nature of a gradually augmenting force, very extensive compared to the areas simultaneously disturbed. No example of modern earthquakes can be brought to render it probable, that mere volcanic agency could upraise the continents which it is capable of shaking.

Yet, as far as we see, a more powerful exertion of the same kind of agency might perform the effects; the principle of this and every other explanation being the necessity of a new adjustment of the exterior form and dimensions of the globe, in consequence of accumulating tension upon it.

But if, for a moment, we abstract our attention from these limited developments of the energies of heat, and consider the elevatory action below continents and islands as the local resultant of diffused subterranean forces, it appears possible to arrive at a more general and equally applicable theory. If, as observations appear to indicate, the ocean once covered all or a large part of the globe, its mean depth must formerly have been less than at present: since the inequalities of the land arise from subterranean convulsions, and the bed of the sea is very irregular, we may admit that the whole or nearly the whole of the terraqueous area has been affected by local displacements. It is the resistance offered by the consolidated crust of the globe to a gradually augmenting *change of internal dimensions*, which caused the disturbing movements. We may therefore allow, that, before the production of a consolidated crust of the globe, the ocean (if it existed in a liquid form) was spread with considerable uniformity over the spherical surface.

From these postulates it must follow, that the actual bed of the sea has been formed by displacements, which, upon the whole, have caused a real subsidence; as the displacements of the land have, upon the whole, caused a real elevation of it. And our confidence in the assumed condition is augmented by observing, first, that they are all implied in the inferences from phenomena already adopted, and that they agree with the sentiment of astronomers as

to the relation of the depths of the sea to the heights of the land.

REFRIGERATION OF THE GLOBE.

In endeavouring to embrace the phenomena of elevation and subsidence in one point of view, it appears almost immaterial whether we suppose the tension of the consolidated crust of the globe, which preceded its fracture and displacement, to have arisen from inward or from outward pressure, —from expansion of, or contraction upon, the interior nucleus,—because, in each case, the pressure would be of the general and gradually accumulating description required; but it seems an unavoidable condition *that the interior nucleus should be of a yielding nature*, to permit the subsidence of large portions of the surface, and accommodate itself permanently to the elevations. This condition leads us to the supposition of great interior heat, which, from general physical considerations, had before appeared very probable, and, from experimental researches, almost a matter of certainty.

If then, finally, we regard this heat as variable,—and, placed as the hot globe is in the vast cold regions of space, through which it radiates its uncompensated rays, it must be so—the globe must be growing cooler—we have at once the general physical cause of the phenomena of disruption and displacement on the crust of the globe, viz. *a collapse of this crust upon the internal nucleus slowly contracted by refrigeration.*

That this is the just inference from the principal laws of phenomena known in geology, we have no doubt; and we think it is free from any considerable objection. An obvious and plausible one is this: If the diameter of the globe

be contracting through refrigeration, the length of the day, as compared to the length of the year, should vary and grow less continually (the particles, which have a certain rotatory velocity, subsiding to describe circles of shorter radius). To which the answer is immediate and satisfactory, viz. that it is true, that, since the days of Hipparchus, the space of two thousand years has shewn no such variation; but that the conduction of heat through the consolidated crust of the globe is known to be so slow as to render that a very short period for the experiment; and further, that the crust does necessarily *not follow* in its contraction *uniformly* on that of the nucleus, but is for a long time in a state of tension, and is at last forced to accommodate itself to new dimensions by *a collapse.*

In corroboration of the doctrine of *a cooling globe*, we might here quote the phenomena of ancient organic life, which certainly agree with it, so far as to shew that vegetation of a tropical character, corals, and other zoophyta, crocodiles, and other reptiles analogous to the animals of hot climates, formerly inhabited the land and sea near the polar circles; and indicate that the surface of these now cold zones was then of a temperature explicable only by a greater heating influence communicated from within the earth.

The most complete test of this theory would doubtless be the deduction of phenomena from it: but this, in the present state of knowledge of the disturbed stratification of the globe, and other associated circumstances, cannot be usefully attempted, unless in the very general expressions of Leibnitz, who, after enumerating the leading features of the changes supposed to be effected in and on the cooling globe by fire and water, states its present condition as one

of less unstable equilibrium,—"Donec, quiescentibus causis atque æquilibratis, consistentior emergeret rerum status."[1]

SUCCESSION OF ORGANIC LIFE ON THE GLOBE.

Man, placed at the head of the last great system of organic life which has been created on the globe, finds innumerable monuments of more ancient systems of being, fitted to earlier conditions of the planet he inhabits. Guided by the principle of adaptation of organic life to physical conditions, which, at every point of the earth and sea, is found now to obtain, and which, were it not discoverable by observation, might be surely inferred from the wisdom and general beneficence of creation, human reason is capable, to a considerable degree, of penetrating within the mysterious veil of antiquity, and restoring the terraqueous conditions of many former periods. Yet, as the perspective of long past time lengthens, the clearness of the picture fades away, and the dim and doubtful light disappoints our further scrutiny. Among the subjects which it is possible partially to illustrate by this investigation, are the relation of former systems of organization to that which is contemporaneous with the human race,—the relations of these one to another,—the creation of the several classes of animals, with reference to their place in the economy of creation.

The relation of former systems of organic life to that which is in activity around us, is of a peculiar description, full of general agreement and innumerable differences. The system of organic life, is perhaps, properly speaking, *one* from the earliest epoch to the present hour; for all fossil organization is reducible to the leading divisions of modern

[1] See Conybeare, *Report on Geology to British Association*, 1832.

nature: and it is this only which allows us to include the existing animals and plants of distant regions as parts of one general arrangement. Fossil, as well as recent, plants are agamous, cryptogamous, or phanerogamous; the same leading divisions of zoophyta, mollusca, crustacea,—many of the same sections of fishes and reptiles, as those which we now behold,—occur in various ancient series of stratified rocks; and this is as much as can be said for the unity of the existing creation, dismembered as it is in different and distant lands and seas.

But when we come to examine minutely the degree of similitude among the correlative parts of those systems, great discrepancies appear. Groups and families of animals now hardly known, or very limited in number, appear predominant in several ancient strata; as, for instance, the brachiopodous and cephalopodous mollusca, large sections of radiaria, particular tribes of crustacea, polyparia, &c. Others, which contain but a few small species in the present economy of nature, are found to have numbered many and gigantic forms in older nature (as the saurian races, salamanders, &c.): the same is true with respect to the vegetable world.

The general result of the whole investigation may be thus expressed and paralleled. The organic forms imbedded in the earth exhibit less and still less agreement with those of existing races, in proportion as they belong to periods further removed from the present: just as, in modern nature, the differences between the productions of one country and another are, in several instances, distinctly proportioned to the distance between them; and just as, in the present system of nature, we see a mixture of agreements and differences between the productions of even remote regions;

so, on comparing fossil and living tribes, the differences are found modified by various agreements. Extinct genera, as producta and spirifera, lie buried with existing genera, as lingula and terebratula, in the ancient mountain limestone. Ammonites, hamites, and belemnites, and other perished forms of life, are mingled, in the chalk, with nautili, pectens, and echinodermata, congenerous with those now in the sea. So with regard to plants. Extinct lepidodendra and stigmariæ lie confused with forms extremely analogous to existing tribes; and crocodiles, like the modern gavial, lived in waters the same or neighbouring to those which nourished the ichthyosaurus, plesiosaurus, and the other almost fabulous monsters of the reptile class.

From these, and a thousand other concurring facts, we venture to present the following conclusion. The organic remains of the different stratified rocks are those of creatures suited to the then conditions of the land and sea respectively; and because those conditions had some general features of agreement with what we now behold, a resemblance to this extent obtains between the fossil and recent creations; but, because of the numerous differences in physical condition, all the details of the organizations differ; and this disagreement is unequal in the different races, because of original inequalities, or their capability of accommodating themselves to new circumstances. This law appears also to be true in the present economy of creation.

On comparing the different systems of strata one with another, and with the present scheme of creation, the same law holds; and we find, in addition, the differences between the organic contents of one system and another, to be in proportion to the interval of geological time elapsed be-

tween them. Thus the fossils of the silurian system may be said to differ from those of the mountain limestone specifically,—from the oolitic system generically,—from the tertiary system, even by whole groups and sections of animal forms. This dependence on time, however, is a coincidence merely, as the analogy of fossils in rocks of analogous composition though different age, is sufficient to prove; the real dependence is on the *change of physical conditions, produced during the lapse of time.*

The present creation, and all the former effects of the Divine will, exhibits a series of beings destined to perform unequal parts in the economy of nature. Some, as plants, are almost passive; others, as animals, perform the functions of active life. Man reasons,—inferior animals obey their instincts. Thus arises a peculiar scale of organization, in which the places of the different living tribes may be marked, with reference to their supposed degree of importance or excellence; and the races of the animal kingdom, in particular, are said to be of higher or lower grade, in proportion to the complexity of their organization, and the variety of their sensations and actions. What is the order of succession of these beings thus reckoned to be inferior and superior? Is the earliest organization known to us, remarkably inferior in complexity to that we now behold? These questions have been frequently proposed, and sometimes answered by an erroneous assertion instead of candid and impartial investigation. The most popular notion appears to be, that as man is undoubtedly the highest type of the last creation of animal life, all the former ones should be viewed as gradually ascending step by step from the inferior tribes towards the point of ultimate perfection; that the several classes of animals, in the ratio of

their rank in creation, should successively appear; the inferior order of forms being found in the lowest and most ancient order of strata.

There is some truth in this. Mollusca occur in the lowest of all the systems of fossiliferous strata (Snowdon); zoophyta, mollusca, crustacea, abound in all those above the lower series. Fishes appear in the silurian rocks; reptiles in the red sandstone; birds in the oolites; cetacea, mammalia, &c., in the supracretaceous beds. But on looking carefully into the matter, it is found capable of a different construction. The fossils are mostly of marine origin; hence the rarity of insects, birds, and mammalia. On the bed of a modern lake, how few bones remain to inform us of the ancient finny inhabitants. The rarity of such remains is remarkable among all the strata, not excepting even the lias; and yet we find, in the silurian rocks near Ludlow, a whole bed of fish-bones and scales, just as in the lias of Westbury. (Mr Lewis of Aymestry.) The order of occurrence of vertebral reliquiæ is generally fishes, reptiles, birds, and mammalia; yet the occurrence of one genus of didelphoid quadrupeds in the oolite of Stonesfield, is a formidable exception; and the general absence of all land animals from the marine strata, offers an escape to those who totally deny this successive production of the classes of animals, according to their grade of organization.

Neither is the order of occurrence of marine reliquiæ such as to afford much countenance to the notion of gradual improvement in organic life. The classes of mollusca are more ancient than those of zoophyta, if we trust our present knowledge, and both older than marine or land plants, —a seeming paradox, since the pre-existence of vegetables

seems capable of being sustained by strong arguments drawn from the relations of animal and vegetable life.

But we may contemplate the question as to the gradual improvement of animal organization in another point of view. Instead of comparing class to class, let us compare those of one group but different geological age. The bivalve mollusca of the oldest Snowdonian rocks were certainly as complicated, nay, more highly organized than the greater number of conchifera of the present ocean, since they belong to the brachiopoda. The crustacea of the silurian system were at least as curiously organized as the limuli of the North American coasts. The goniatites of the mountain limestone are far more curiously constructed than the nautili which lie with them, and also inhabit modern oceans. The belemnites and ammonites, turrilites and other extinct genera of the oolite and chalk, reveal to us an extinct order of cephalopoda, larger, more powerful, and more curiously organized, than existing loligines and sepiæ.

It is evident, therefore, that the whole notion of a gradual amelioration or enrichment of the animal organization may be dismissed as a mere illusion of the fancy of a finite being, who vainly transfers to the work of the Almighty the pattern of his own limited labours.

The systems of organic life have always been adjusted to the actual conditions of the land and sea. When water covered the globe, life was marine; as land arose, and new conditions supervened, terrestrial life was created; old races died away; with new circumstances, new creations were called into being to supply their place; and at length the physical revolutions of the globe brought that wonder-

ful variety of external circumstances to which organic life is at this day adjusted.

Thus a perpetual stimulus is afforded to man, the last great creation of Divine power, to study the works of his Maker, and through them to receive proofs "strong as Holy Writ" of the long-enduring providence of the Almighty, whose appointed plans the permitted violence of the physical agencies of nature, amidst all their irregularities, exactly fulfil; and whose care, now so manifest for his human creatures, has never been withheld from the meaner forms of every age since the time when the earth became tenanted by beings capable of enjoying their own existence.

GEOLOGICAL TIME.

The chronology adopted by geologists is liable to an inherent uncertainty or indefiniteness, quite different in its nature from the sources of error in ancient history. In the history of human affairs, the whole period which elapsed between the two epochs chosen as limits is known or supposed to be so; but the intervening occurrences cannot often be correctly placed in their true succession. In geology, on the contrary, the whole period included between the limits is, and perhaps must ever be, absolutely unknown; yet the succession of occurrences is, in general, clearly ascertained. Again, it frequently happens, that the histories of different nations have no common features for very long periods, but remain insulated. This defect is less sensible in geology; for some of the monuments of contemporaneous physical conditions of the globe are very widely diffused.

The true scale of geological chronology is that of the

stratified rocks. According to the view previously advocated, the several systems of strata mark periods more or less exactly definable; the last, or supratertiary period, which descends to the present era of the globe, being, as yet, one of the least defined in its limits.

It has been already explained that historical time, commencing with the human race, is not yet united to geological time. Whenever the exact place of the creation of man, on the scale of geological phenomena, can be fixed, and the two scales continuously united, we may be able to advance, without certainty of utter failure, to the consideration of the problem lately proposed for a prize essay by the Royal Society of London, viz. the translation of geological into astronomical periods.

At present the chronology of the globe, starting from the origin of the stratified rocks, and including the whole series of successions of organic beings, and all the convulsive disturbances of the cooled and consolidated crust, recognises many successive periods of unknown duration. Neither does it appear possible to know their duration, or even the limits of error within which they fall. How, then, it may be asked, do geologists justify their confident assertions of the very great antiquity of particular rocks as compared with the few thousand years of history? To this the reply is simple. Many of the ancient stratified rocks were formed in the sea by processes perfectly similar to those which go on at this day; and, *in some cases*, we may believe not at all more rapid in their effects. The laminated sandstones often mark what appears to be the ripple of a gentle tide, and the successive deposits of agitated water; the shelly limestones sometimes prove very slow deposition of even a single layer of calcareous rock; the

alternation of igneous and sedimentary rocks gives us the similitude of volcanic submarine eruptions. Now, if we compare with the sedimentary strata of any particular period the most similar products of the present day,—the new land on the Adriatic,—the filling up of the Nile Valley,—the shallowing of the Bay of Bengal,—we shall be impressed with the necessity of allowing a long period for the production of a single stratified formation.

Again, if we recollect, that during these periods many creations of new and destructions of old races of animals and plants happened,—and that, ever since the records of human art, the embalmed body or sculptured effigies, have given the means of judgment, no change has happened to modern races; that two or three thousand years have not changed the forms of animals known to the early Egyptians; we shall see the impropriety of imagining such changes to have been of quick succession in the earlier eras of nature.

And when we behold conglomerate rocks which hold fragments of other earlier deposits, and, in these fragments, the organic remains of still earlier periods which had already undergone their peculiar mineral changes; when we collect the history of such an organic form,—its existence in the sea,—its sepulture in a vast oceanic deposit of limestone, or in a littoral aggregation of sandstone,—the induration of this rock,—its uplifting by subterranean forces,—the rolling of it to pebbles,—the reunion of them in a totally different kind of substance,—it is evident that no greater folly can be committed than to think to serve the cause of truth by contracting the long periods of geology into the compass of a few thousand years.

The task of reducing these long periods to any definite

scale, is at present entirely hopeless. Three possible modes seem open to us; but we cannot advance a step in any one of these, without immediate aid from visionary and delusive guides.

1. Could we know the rate of secular refrigeration of the globe, either from general physical considerations, or a summation of the effects of convulsive movements, a basis of inquiry would be established. But who will dare to attempt the solution of such a problem?

2. Could we know the mean or extreme rate of production of stratified deposits at the present day, this would enable us to conjecture the lengths of some geological periods, and with double hazard refer others to this conjectural scale; but even this unsatisfactory estimate would be liable to the further and fatal error of not knowing the ratio of the forces in the different periods. To assume this ratio is only to augment in a still higher degree the amount of improbability.

3. Perhaps the safest, certainly the most alluring, of the three methods which geology may follow in this dark research, is that which is founded on a strict scrutiny of the history of organic remains. The life of animals and plants is a phenomenon distinctly related to annual periods; and, for some systems of strata, as for example the tertiary, the resemblance of specific forms is enough, the great number of coincidences being considered, to authorize deductions as to the length of life of fossil and recent species of marine mollusca. But here the want of knowledge is utterly fatal. Who can tell us the average term of life of marine molluscous animals, sufficiently comparable with tertiary shells, to form a basis of good reasoning?

It is evident that we have no knowledge capable of be-

ing employed, in the magnificent problem of the age of the crust of the globe, at all equal to the difficulty which meets us on the very threshold. Until the constants of nature which relate to the dependence of organic or inorganic phenomena on annual periods be known, the determination of the antiquity of any of the marine stratified rocks must be despaired of.

GENERAL RESULT.

We have thus briefly presented some fundamental inferences which must be embodied in any rational theory of geology.

To combine these and other sound inferences is the true business of theory: it ought not yet to be attempted, for though the notion of a slow decrease of the heat of the globe being the primary law of causation, is perhaps continually forcing itself on the attention of geologists, as well calculated to account for the consolidation, disruption, and irregularity of elevation of the crust of the globe, and almost necessary to explain its actual condition of sensible equilibrium; though it is inconsistent with no astronomical, mechanical, or chemical truth, and meets without difficulty the problems suggested to zoology and botany by the monuments of ancient organic life, still the development of this truly general theory requires a far more exact survey of the structure of the globe, and a far more intimate acquaintance with the effects of modern terraqueous agencies than we now possess.

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